ROLE OF MRCP IN EVALUATION OF BILE DUCT INJURIES

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Dedicated

to

my Family

&

Teachers

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Dr. Kanav

LIST OF ABBREVIATIONS

CBD	Common Bile duct
CE MRC	Contrast enhanced Magnetic resonance cholangiography
CHD	Common hepatic duct
CT	Computed tomography
ERCP	Endoscopic retrograde cholangiopancreatography
GB	Gall bladder
GD-BOPTA	Gadobenate dimeglumine
GD-EOB-DTPA	Gadoxetate disodium
IHBRD	Intrahepatic biliary radical dilatation
LFT’s	Liver function tests
LHD	Left hepatic duct
MIP	Maximum intensity projection images
MRCP	Magnetic resonance cholangiopancreatography
MRI	Magnetic resonance imaging
PTC	Percutaneous transhepatic cholangiography
RHD	Right hepatic duct
RPD	Right posterior duct
T2WI	T2 weighted images
USG	Ultrasonography

ABSTRACT

Introduction: Bile duct injuries can appear as biliary dilatation, excision damage, strictures, fluid collections, or free fluid accumulation. Due to the vague clinical signs and potential severe consequences of delayed diagnosis, imaging plays a crucial role in early detection and management of bile leaks. Magnetic Resonance Cholangiopancreatography (MRCP) is a non-invasive imaging method used to visualize both the intrahepatic and extrahepatic biliary systems as well as the pancreatic ductal system. Therefore, MRCP serves as a valuable diagnostic tool for characterizing and anatomically classifying these bile duct injuries, aiding in the planning of surgical repairs and other necessary treatment.

Aims & Objectives: 1. To assess the role of MRCP in evaluation of Bile duct injuries.
2. To assess the added advantage of using intravenous hepatobiliary contrast in evaluation of Bile duct injuries wherever possible.
3. To correlate the imaging findings with ERCP, surgical findings or clinical follow up wherever possible.

Materials and Methods: This study was carried out at Dayanand Medical College and Hospital, Ludhiana on 42 patients with clinical evidence of bile duct injury who were referred for MRCP to the Department of Radiodiagnosis. The study was conducted for a duration of one and half year from September 2022 to March 2024 after the approval of research and ethical committee.

Results: Non- contrast MRCP had a sensitivity of 60.6% and specificity of 71.4% in detecting and localizing bile duct injuries with a concordance of 62.5% with surgery/ERCP findings whereas contrast enhanced MRCP had a sensitivity of 81.8% and specificity of 85.7% with a concordance of 82.5%. Combination of non-contrast and contrast enhanced MRCP had a sensitivity of 90.9% and specificity of 85.7% with a concordance of 90% with surgery/ERCP in detecting and localizing bile duct injuries.

Conclusion: MRCP is an excellent tool for assessment of the biliary tree in assessment of biliary tree variations, involvement of the bile ducts by disease and assessment of the injuries to both intra-hepatic and extrahepatic biliary system. MRCP serves a roadmap for planning therapeutic interventions in various subsets of patients.

Keywords: MRCP, ERCP, Biliary Tree

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INTRODUCTION

Bile duct injury is a known complication of cholecystectomy which is associated with high degree of morbidity and mortality.[1–3]Open and laparoscopic cholecystectomy are the mainstay options for management of patients with cholelithiasis. Majority cholecystectomies are laparoscopic as they are associated with less post operative pain, shorter stay in hospital and less morbidity.[4] The incidence of bile duct injury reported for open cholecystectomy varies from 0 to 0.5% and laparoscopic cholecystectomy has incidence of 0 to 1.2%.[1-3] Bile duct injuries can be caused by inaccurate cutting of bile duct, displacement of surgical clips, stricture formation or leakage by thermal injury with use of electrocautery.[5] Risk Factors for bile duct injury include obesity, congenital or anomalous anatomic variants, Gall bladder inflammation and lack of experience of operating surgeon.[6,7]

Injuries to the extrahepatic biliary system due to blunt trauma are infrequently documented. Minor tears can manifest as leaks over time, potentially resulting in fistula formation or narrowing (strictures).[8] The majority of bile duct injuries resulting from trauma typically coincide with liver damage and manifest across a range of conditions, spanning from partial or complete transections to simple contusions and wall hematomas.[9–16] Among patients with extrahepatic biliary injury , 85% experience injuries affecting the gallbladder, while isolated bile duct injury is observed in only 15% of cases. In instances of extrahepatic bile duct injuries, the most common locations are near the hepatic hilum or within the pancreatic head. The effect of blunt trauma on the abdominal region can cause the liver to rise, stretching the hepatoduodenal ligament to the point of tearing at the junction of the bile duct. Moreover, in the vicinity of the sphincter of oddi, there is a natural increase in intraluminal pressure, which is suddenly heightened by the traumatic event, resulting in the rupture of the bile duct wall in this area.[17,18]

The onset of a potential biliary leak can initially manifest with nonspecific symptoms, including nausea, vomiting, bloating, diffuse

abdominal pain, overall discomfort, and loss of appetite. Occasionally, despite significant bile accumulation in the abdomen, patients may rarely exhibit the clinical signs of biliary peritonitis. The progression of a biliary leak tends to be subtle due to the presence of these vague symptoms. In instances where there is a stricture at the level of the common bile duct (CBD), and the CBD is mistaken for the cystic duct, patients may present with Charcot's triad, characterized by pain in the right upper abdomen, fever, and jaundice.[19]

Bile duct injuries can manifest in various forms, including:[20]

Leak: Bile leaks occur when there is a breach or disruption in the continuity of the bile duct, leading to the leakage of bile into surrounding tissues or cavities.

Stricture: Bile duct strictures involve the narrowing or constriction of the duct, which can result from scarring, inflammation, or trauma. Strictures can impede the flow of bile and may lead to complications such as jaundice or cholangitis.

Complete Transection: This refers to a complete severing or cutting through of the bile duct, resulting in the separation of the duct into two distinct ends. Complete transections often require surgical intervention for repair.

Excision of a segment of Duct: In some cases of severe injury or disease, a segment of the bile duct may need to be surgically removed. This procedure aims to remove damaged or diseased tissue while preserving the function of the remaining duct.

Ligation of a Major Bile Duct: Ligation involves the intentional blocking or tying off of a major bile duct, which may be performed as a surgical intervention in certain medical conditions. However, unintentional ligation of a bile duct can occur as a complication during surgery and may lead to bile duct injury.

Traditionally, bile duct injuries have been classified using either the Bismuth or Strasberg classification systems. The Bismuth classification primarily focuses on the localization of biliary strictures in relation to the

distance from the biliary confluence. However, it doesn't cover the full range of bile duct injuries.[21]

Recognizing this limitation, Strasberg expanded upon the Bismuth classification to make it more comprehensive. Their modification included additional types of bile duct injuries, providing a broader framework for categorizing these injuries.

The Strasberg-Bismuth classification categorizes injuries and biliary strictures according to their anatomical position within the biliary system in relation to the biliary confluence.

Strasberg classification:[22]

Type A: injury to the cystic duct or from minor hepatic ducts draining the liver bed

Type B: occlusion of the biliary tree, commonly aberrant right hepatic duct

Type C: transection without ligation of sectoral duct

Type D: Lateral injury to a major bile duct

Type E: injury to the main hepatic duct; classified according to the level of injury

E1 (Bismuth type 1): injury more than 2 cm from the confluence

E2 (Bismuth type 2): injury less than 2 cm from the confluence

E3 (Bismuth type 3): injury at the confluence; confluence intact

E4 (Bismuth type 4): destruction of the biliary confluence

E5 (Bismuth type 5): injury to the aberrant right hepatic duct

Since clinical signs and symptoms of bile leaks often lack specificity, making them challenging to diagnose promptly. Delay in recognizing bile leaks can lead to severe complications and increased morbidity and mortality rates. Therefore, imaging techniques play a crucial role in making an early diagnosis and guiding treatment decisions.[23]

Biliary leaks can occur at various sites, with common locations including injured ducts, the cystic duct stump, and the gallbladder stump. Following cholecystectomy, fluid collections in the gallbladder bed are relatively common, occurring in up to 14% of patients. Typically, these collections resolve spontaneously. However, if fluid

collections persist beyond a week or if fluid is found outside the gallbladder bed, suspicion of a biliary leak or injury is raised.[24]

The initial management of individuals with biliary leaks is dependent upon the nature of injury and timing of its detection. Minor leaks can be managed by endoscopic intervention whereas major leaks are managed by surgical approach like roux en y hepaticojejunostomy. Hence, it is imperative to precisely ascertain the morphological characteristics of the injury and delineate the anatomy of the proximal biliary tree. This data is indispensable for formulating the correct approach to biliary reconstruction and greatly influences the patient's long-term prognosis.[20-25]

Various methods utilized in diagnosing bile duct injuries are Ultrasound (USG), Percutaneous Transhepatic Cholangiography (PTC), Endoscopic Retrograde Cholangiopancreatography (ERCP), direct cholangiography, and Magnetic Resonance Cholangiopancreatography (MRCP). These techniques facilitate determining the extent of injury, identifying fluid accumulations or the existence of ascites and detecting potential vascular damage.[26,27]

The primary aim of investigations should prioritize achieving diagnosis with minimal risk of complications and at the lowest cost possible. Specifically, more invasive procedures like ERCP and PTC serve to accurately diagnose the anatomical location of injury and provide therapeutic measures such as decompression or dilation of the biliary system.[21] However, ERCP's usefulness is restricted when addressing complete stenosis since it only visualizes the lower portion of the obstruction and does not provide a clear outline of the proximal biliary tract.[28] Nonetheless, it's essential to recognize that these procedures can result in complications such as acute pancreatitis, hemorrhage, perforation, aspiration, and adverse reactions to contrast media or premedication.[29]

MR cholangiography (MRCP) stands out as a non-invasive and precise method for evaluating bile duct injuries post-surgery.[21] This approach enables precise determination of the level of biliary injury, crucial for preoperative strategizing. In comparison to ERCP, MRCP offers

significant advantages by accurately visualizing biliary tree obstructions upstream of a blockage, pinpointing abscesses or fluid collections around the liver, identifying sites of bile leakage, and assessing liver parenchyma and pancreas conditions.[30]

In MRCP, the fundamental principle relies on the fact that bodily fluids like bile and pancreatic secretions exhibit high signal intensity on heavily T2-weighted magnetic resonance sequences, appearing bright, while surrounding tissues produce minimal signal and appear dark. Typically, MRCP is conducted using heavily T2-weighted sequences employing fat spin echo or SSFE (Single Shot Fast Spin Echo) techniques, alongside both thick collimation (single section) and thin collimation (multisection) methods with a torso phased array coil. The coronal plane is utilized to present cholangiography images, while the axial plane is employed to assess the pancreatic duct and common bile duct (CBD).[31]

T1-weighted (T1w) contrast-enhanced Magnetic Resonance Cholangiography (CE-MRC) makes use of hepatocyte specific contrast agents like gadobenate dimeglumine (Gd-BOPTA) and gadolinium ethoxybenzyl diethylenetriamine penta-acetic acid (Gd-EOB-DTPA) and is a newer method showing good results in visualizing nondilated bile ducts and detecting bile leakage.[32–36] Both Gd-BOPTA and Gd-EOB-DTPA are taken up by hepatocytes via an anionic transport system after the vascular phase. Around 3–5% of injected doses of Gd-BOPTA and 50% of Gd-EOB-DTPA are eliminated through the human biliary system.[37,38] As a result, Gd-EOB-DTPA may provide efficient biliary imaging within a shorter timeframe (10–20 minutes) compared to Gd-BOPTA (60 minutes).[39] Gd-EOB-DTPA-enhanced MRC facilitates the detection of ongoing bile leakage by directly visualizing the extravasation of contrast material into fluid collections, thereby disclosing the location and nature of the biliary injury.[37–39]

Biliary Anatomy

The biliary tree can be classified as intra hepatic and extra hepatic bile ducts.

INTRAHEPATIC BILE DUCTS:

The individual drainage system for bile runs alongside the portal venous supply.

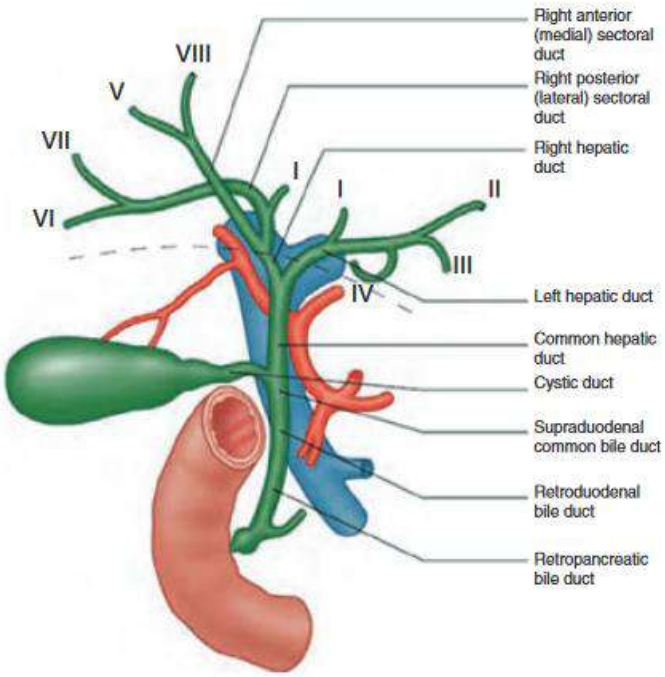
The right hepatic duct divides into two main branches: one for the posterior segments (VI and VII), which follows a mostly horizontal path, and another for the anterior segments (V and VIII), which tends to run more vertically. Typically, the right posterior duct merges with the right anterior duct, forming the right hepatic duct when approached from a left (medial) direction. The left hepatic duct collects tributaries from segments II–IV. The bile duct from the caudate lobe typically connects to either the left or right hepatic duct. Ducts in the left hepatic lobe are positioned more toward the front compared to those in the right lobe.[40] This is particularly crucial during contrast cholangiograms, as individual ducts may not be clearly visualized due to their proximity.

EXTRAHEPATIC BILIARY SYSTEM:

The common hepatic duct originates above the cystic duct and is formed by the fusion of the typically short right hepatic duct and the left hepatic duct, usually occurring just outside the porta hepatis (around 1 cm below the liver's edge). It runs downwards and forwards from the porta hepatis within the hepatoduodenal ligament, alongside the posteriorly located portal vein and the medially positioned hepatic artery. As it descends, it curves forwards and then backwards, passing over the right portal vein and merging with the cystic duct to create the common bile duct (CBD). The CBD typically divides into segments above the pancreas, within the pancreas, and near the ampulla.

The common bile duct initially travels along the unattached edge of the lesser omentum and enters the pancreas's head after passing behind the first segment of the duodenum within the hepatoduodenal ligament. It descends downwards and backwards, nestled within the posterior surface of the pancreatic head, where it merges with the pancreatic duct of Wirsung. This section takes a brief intramural path before emerging at the back and middle of the duodenum through the major papilla of Vater. Measuring 7 cm in length with an average diameter of 7.4 mm, the common bile duct combines with the main pancreatic duct

in the second part of the duodenum to create the ampulla of Vater. This typical biliary anatomy is believed to be present in about 58% of the people.[40]



Picture 1: Normal Extrahepatic and Intrahepatic Biliary Anatomy[41]

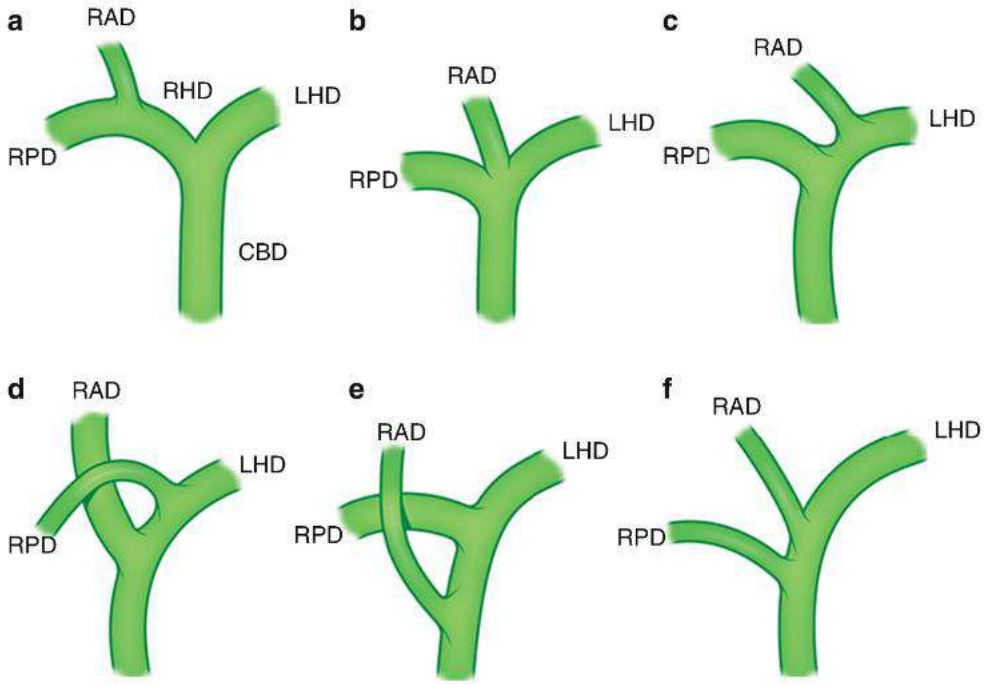
COMMON ANATOMIC VARIANTS OF THE BILIARY TREE

The most common anatomic variants in the branching of the biliary tree is the drainage of the right posterior duct into the left hepatic duct before its confluence with the right anterior duct and reported to occur in 13–19% of the population.[40] In approximately 12% of the population, the right posterior duct will empty into the common hepatic duct. [40] Another common variant (11%) of the main hepatic biliary branching is the so-called triple confluence, which is an anomaly characterized by simultaneous emptying of the right posterior duct, right anterior duct, and left hepatic duct into the common hepatic duct.[40]

UNCOMMON ANATOMIC VARIANTS OF THE BILIARY TREE

1) Aberrant hepatic duct: has an anomalous confluence pattern and is the only bile duct draining a particular hepatic segment. The direct drainage of the right hepatic duct into cystic duct is present in approximately 2% of the population.[40]

2) Accessory hepatic duct: is an additional bile duct draining the same area of the liver. It is observed in approximately 2% of patients & may originate from and run their course along both the left or right ductal system.[40]



Picture-2: Variants of Biliary tree[42]

COMMON VARIANTS OF THE CYSTIC DUCT

There are three common variants

1. A low cystic duct insertion, characterized by a fusion of the cystic duct with the distal third of the extrahepatic bile duct(9%).[40]

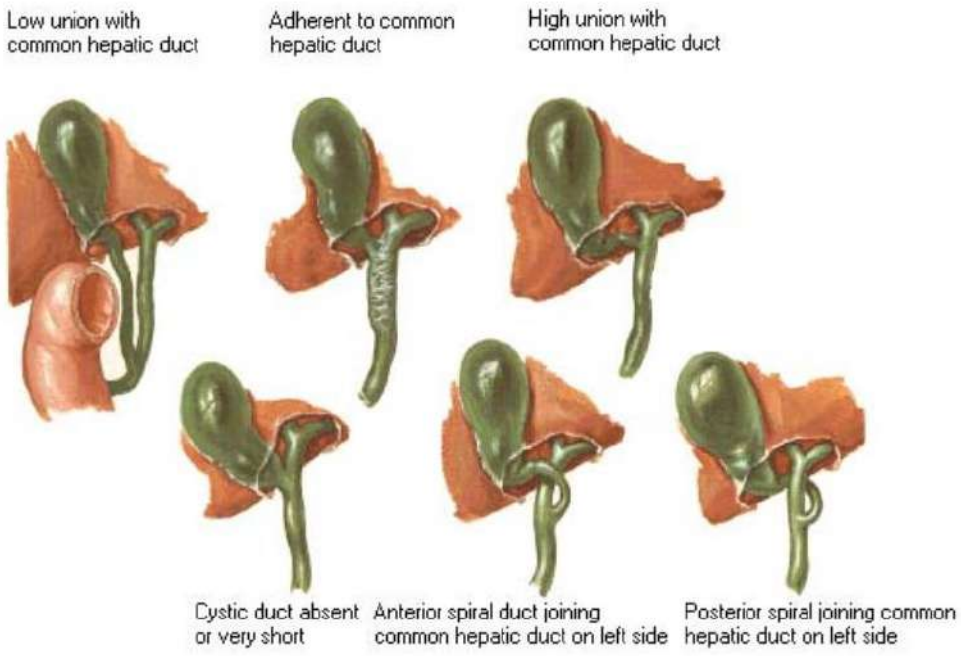
2. A low medial cystic duct insertion, in which the cystic duct drains into the left side of common hepatic duct in its distal third (10–17%).[40]

3. A parallel course of the cystic duct and common hepatic duct when cystic duct follows a closely adherent course, parallel to the common hepatic duct over at least a 2-cm segment(1.5–25%).[40]

UNCOMMON ANATOMIC VARIANTS OF THE CYSTIC DUCT

1) High fusion of the cystic duct with the common hepatic duct.

2) Aberrant fusion of the cystic duct with the right or left hepatic duct.


Low union with common hepatic duct
Adherent to common hepatic duct
High union with common hepatic duct
Cystic duct absent or very short
Anterior spiral duct joining common hepatic duct on left side
Posterior spiral joining common hepatic duct on left side

Picture-3: Variations of cystic duct[43]

AIMS AND OBJECTIVES

1. To assess the role of MRCP in evaluation of Bile duct injuries.
2. To assess the added advantage of using intravenous hepatobiliary contrast in evaluation of Bile duct injuries wherever possible.
3. To correlate the imaging findings with ERCP, surgical findings or clinical follow up wherever possible.

REVIEW OF LITERATURE

Various studies have been done to study the role of MRCP in evaluation of bile duct injuries.

T S Yeh et al [44] (1999) carried out a retrospective investigation by examining the medical records of five individuals who had received laparoscopic cholecystectomy and were suspected of experiencing significant bile duct injuries. These patients all underwent magnetic resonance cholangiopancreatography (MRCP), followed by either endoscopic retrograde cholangiopancreatography (ERCP), percutaneous transhepatic cholangiography (PTC), or both, for traditional cholangiography. The research aimed to compare the results of MRCP with those of conventional cholangiography. Out of the patients examined, four were diagnosed with bile duct injuries, while the remaining patient experienced temporary jaundice caused by gallstones becoming displaced into the common bile duct (CBD) during laparoscopic cholecystectomy. The MRCP scans proved to be more effective diagnostically than conventional cholangiography in detecting bile duct injuries in four patients. In these instances, ERCP only revealed the obstruction of the CBD, necessitating PTC to visualize the upper biliary system. However, MRCP simultaneously displayed the entire biliary system both before and after the injured or narrowed areas.

The research indicated that MRCP is the preferred diagnostic test in cases where there is suspicion of bile duct injury following laparoscopic cholecystectomy

In a prospective study conducted by Tahir R. Khalid et al[20] (2000), MRCP was performed on ten postoperative patients suspected of having bile duct injuries after surgery. The patients included nine females and one male, ranging in age from 17 to 79 years. The aim of the examination was to detect biliary dilatation, excision injury, stricture, fluid collection, and free fluid on MRCP. The results were compared with endoscopic retrograde cholangiopancreatography, percutaneous transhepatic cholangiography, surgery and clinical follow-up. Three patients showed normal MRCP findings and remained

asymptomatic during clinical follow-up. Among the remaining cases, four patients exhibited evidence of bile duct excision injury on MRCP, which was subsequently confirmed during surgery. Furthermore, among these five patients, one individual was identified with a stricture, which was verified by percutaneous transhepatic cholangiography. Within this group, one patient was diagnosed with a Bismuth type I injury, two with type II injuries, one with a type III injury, and one with a type IV injury. Additionally, MRCP revealed indications suggestive of cystic duct leakage in two patients, which were later confirmed through cholangiography.

They concluded that MRCP is highly proficient in detecting postoperative biliary strictures and excision injuries, offering comprehensive characterization and anatomical classification crucial for strategizing corrective surgical interventions. Moreover, it can signal the probability of cystic duct leaks in individuals who have undergone cholecystectomy.

In a prospective study conducted by K. Vitellas and et al[45] (2002), eleven patients suspected of having bile duct leaks post-cholecystectomy were studied. Contrast MRCP was assessed for extent of opacification of ducts and the existence and localization of bile leak, occlusion and calculi. MRCP was compared with ERCP (n = 10) and PTC (n = 1). Contrast excretion was observed in biliary system in each patient. Conventional post contrast cholangiography detected bile duct leaks in six patients and ruled them out in five patients, with one false-negative and one false-positive finding for bile duct leak (sensitivity, 86%; specificity, 83%).The study concluded that contrast-enhanced MRCP can effectively locate biliary leaks in patients post cholecystectomy.

In a study by Luis Bujanda et al.[46] (2003), a prospective blinded investigation was conducted comparing the effectiveness of MRCP and ERCP in diagnosing biliary tract lesions in 10 postoperative patients suspected of having such issues. MRCP was performed within 72 hours prior to ERCP. Diagnosis was confirmed based on surgical and ERCP findings, which included assessment for various factors such as

dilatation of bile ducts, excision injury, occlusion, localized fluid collection, and free fluid. The patients consisted of 3 males and 7 females. Lesion types, classified according to the Bergman classification, were distributed as follows: 5 patients were categorized as type C, 3 patients as type D, 1 as type B, and 1 as type A. ERCP failed to diagnose in two cases and was unable to determine a treatment approach in five patients. However, MRCP was able to diagnose all cases accurately.

The research concluded that MRCP efficiently identifies biliary tract lesions post-surgery and assists in deciding the best therapeutic strategy.

Alfonso Ragozzino, Rosaria De Ritis et al[21] (2004) conducted a prospective study involving nineteen patients (14 women and five men) with suspected bile duct injury following laparoscopic cholecystectomy (17 patients) and open cholecystectomy (two patients).They used Bismuth classification to classify the injuries. The final diagnosis relied on surgical findings, PTC, ERCP and clinical follow up. Among the cohort, sixteen patients exhibited bile duct injuries, with two having Bismuth type I injury, one type II injury, eleven type III injuries, and one patient each with type IV and V injuries. The study concluded that MR cholangiography serves as a precise diagnostic tool for identifying postoperative bile duct injuries. This modality helps us visualize the entire biliary system whereas assessment in case of ERCP and PTC is quite limited when it comes to visualization of biliary tree proximal to the obstruction.

Mi-Suk Park, Ki Whang Kim et al[47] (2004) carried out research in seven patients suspected of experiencing biliary issues after laparoscopic cholecystectomy using and comparing non-contrast MRCP , contrast enhanced MRCP and ERCP. Complications were assessed by examining the extent and severity of biliary injury, bile leak, and the presence of calculi. MRCP identified various conditions such as transection and blockage of the CBD with bile leak, incomplete narrowing of the CBD with bile leak, leak from the cystic duct, incomplete ligation of an abnormal right hepatic duct, and bleeding

unrelated to biliary system. Surgical and ERCP results concurred with these diagnoses, except for one instance where MR cholangiography incorrectly identified a partial narrowing of the bile duct as a complete blockage.

The study concluded that that utilizing both conventional T2-weighted and MnDPDP-enhanced T1-weighted MR cholangiography together could eliminate the necessity for supplementary imaging examinations in the assessment of biliary complications following cholecystectomy.

F. Pilleul et al[48] (2004) carried out a prospective study involving 11 patients suspected of having bile duct leaks post trauma (n=5) or hepatobiliary surgery (n=6), excluding those with suspected leaks after cholecystectomy. All patients underwent contrast enhanced MRCP and findings were compared with surgery or ERCP findings. Opacification of biliary system was achieved in all patients. No false positive or negative finding was reported using MRCP.

The study concluded that contrast enhanced MRCP is a noninvasive modality capable of providing functional information of biliary system with excellent delineation of biliary tree.

K. El-Ella et al[49] (2004) conducted a retrospective study involving eighteen patients between July 1998 and September 2000. The repair technique involved utilizing Roux-en-Y hepaticojejunostomy with the establishment of mucosa-to-mucosa anastomosis. The study recorded patient presentations, ages, and genders. Patients presented with a range of symptoms, including pain, jaundice with or without cholangitis in 13 cases, bile leakage resulting in biliary peritonitis in three cases, and the formation of external biliary fistula in two cases. Despite a reduced occurrence of complications, MRCP emerged as a more valuable diagnostic tool, aiding in surgical planning by delineating both proximal and distal ducts relative to the site of injury or stricture in 14 out of 18 patients. Bile duct injuries were categorized based on the Bismuth classification, with one patient categorized as type I, five as type II, eleven as type III, and one as type IV. All patients successfully recovered without complications during the immediate postoperative phase. Only two patients experienced strictures within four months

post-surgery, with one managed conservatively, while the other underwent repeated dilatation and stenting.

The study concluded that hepaticojejunostomy stands out as the preferred method for addressing bile duct injuries, ensuring sufficient biliary drainage. Moreover, MRCP was identified as an optimal diagnostic approach in cases where bile duct injury is suspected subsequent to laparoscopic cholecystectomy.

M. Aduna, J. A. Larena et al.[50] (2005) conducted a prospective study involving 34 patients suspected of bile duct leak following laparoscopic cholecystectomy. They examined the effectiveness of contrast enhanced MRCP in identifying and pinpointing biliary leakage. Among the group, 20 patients were confirmed to have bile duct leakage through surgical intervention, ERCP, or drainage. MRCP detected leaks in nineteen of the twenty patients, while ruling out leaks in the remaining fourteen patients, resulting in a sensitivity of 95% and specificity of 100%.

The study concluded that contrast-enhanced MRCP effectively identifies both the existence and site of bile leak in individuals post cholecystectomy.

I Kamaoui, L Milot et al.[51] (2007) carried out a retrospective analysis on 25 individuals who had a strong clinical suspicion of bile leak (18 men and 7 women). Through a combination of imaging results, laboratory test results, and clinical examinations, clinical suspicion was established. 20 patients had a bile leak detected by contrast enhanced MRCP using Teslascan and 17 of these patients had the leak's location identified. Drainage , ERCP, surgery, conservative surveillance and medicinal treatment were among the management modalities based on MR findings. Two patients died from complications related to infection, while the remaining eighteen cases had a positive prognosis. The study found that, apart from diagnosis of bile leak, MRCP combined with Teslascan injection accurately localizes the site of leak, which facilitates the use of best practices in management.

L. Salvolini, C. Urbinati et al [52] (2011) evaluated the efficacy of contrast-enhanced MRCP using hepatobiliary contrast in evaluating the biliary system after hepatic surgery. Both unenhanced MR cholangiopancreatography (MRCP) and post-contrast MRC were performed for 142 patients, resulting in successful visualization of the biliary tract in every case. Out of the patients, 22 were diagnosed with confirmed biliary complications following surgery. MRCP identified lesions in 64% of cases, while the remaining 36% exhibited suspected abnormalities without clear characterization. In contrast, CE-MRC provided a definitive diagnosis in 100% of cases.

The study concluded the use of hepatobiliary-specific contrast agents enables accurate and thorough assessment of abnormalities in the biliary tract, especially in the evaluation of postoperative complications.

A. Castellanos et al[53](2012) conducted a prospective study involving twenty-three patients exhibiting symptoms suggestive of bile leaks. These patients underwent non-contrast MRCP, followed by Gd-EOB-DTPA-enhanced MRCP. The outcomes of contrast-enhanced MRCP were juxtaposed with clinical observations, surgical repair results, and findings from endoscopic retrograde cholangiopancreatography and percutaneous transhepatic cholangiography. Among the patients, Gd-EOB-DTPA-enhanced MR cholangiography yielded negative results in 13 cases. Bile leaks were detected in 10 patients, occurring after partial hapetectomy for focal liver lesions(n=3), gall bladder surgery (n=4), hepatobiliary transplant surgery (n=2), and hapetectomy for cholangiocarcinoma (n=2). The diagnostic precision of Gd-EOB-DTPA-enhanced MR in identifying or ruling out bile leaks was 100%.

The study concluded that contrast enhanced MRCP is a precise modality for detecting bile leaks following hepatobiliary surgery, potentially obviating the need for other invasive diagnostic methods that carry inherent risks.

M. Kantarci, B. Pirimoglu et al.[54] (2013) conducted a prospective study involving ninety-nine patients with suspicion of biliary complications. These patients underwent T2-weighted MRCP and T1-weighted contrast-enhanced (CE) MRC using Gd-EOB-DTPA to detect biliary leaks. Two observers independently and collectively reviewed the image sets. The MRC findings were compared with surgery findings and PTC results.The combination of Gd-EOB-DTPA-enhanced MRC and T2w-MRC showed superior accuracy in locating biliary leaks ($P < 0.05$) as compared to T2w-MRC alone.

The study concluded that Gd-EOB-DTPA-enhanced MRC provides complementary information to T2w-MRC findings, enhancing the identification and localization of bile extravasations.

In a retrospective study by G. Ratcliffe et al.[55] (2014), conducted a review of 16 consecutive patients who had undergone contrast enhanced MRCP to assess suspected bile leaks .Endoscopic assessment revealed bile leaks in 6 patients which were accurately detected by reviewers analyzing MRCP resulting in a 100% sensitivity. One reviewer inaccurately diagnosed a bile leak among the negative cases which lead to a specificity of 98%.Contrast enhanced MRCP accurately diagnosed site of leak in 80% of the cases.

The study concluded that Gadolinium-EOB-DTPA-enhanced MR demonstrates high sensitivity and specificity in detecting bile leaks.

A. Marth, T. Auer et al[56] (2023) conducted a retrospective study involving 39 patients who underwent Gd-EOB-DTPA-MRCP for suspicion of bile leak .The presence of bile leaks and leakage site was assessed by three reviewers .The imaging findings were compared with surgery and other interventional procedures.

Contrast enhanced MRCP accurately detected bile leaks in 25 patients. However, it was seen that the location of bile leaks significantly different between postoperative where location was mostly central and peripheral and trauma patients where location was intraparenchymal.

The researchers concluded that Gd-EOB-DTPA-MRCP reliably detects and precisely locates bile leaks in postoperative and trauma patients which enables treatment planning.

M. Leguia et al[57] (2024) conducted a retrospective case series study comprising patients on which contrast MRCP was performed with suspicion of bile duct injury post-cholecystectomy. MRCP findings were compared with surgery and ERCP findings. The study included 20 patients and in all 20 patients, lesions were identified on MRCP with 19 confirmed by surgery or ERCP .The most common injuries were Strasberg Type E2 and E4, seen in five patients each. The kappa index was 1 for detecting bile duct injury and 0.9 for the Strasberg classification.

Contrast-enhanced magnetic resonance cholangiography has emerged as a technique with a notably high positive predictive value and nearly flawless interobserver agreement in the diagnosis of bile duct injuries following cholecystectomy.

MATERIALS AND METHODS

SOURCE OF DATA

This study was conducted over a period of one and half year from 15th September 2022 to 15th March 2024 on patients with clinical evidence of bile duct injury referred for MRCP to the Department of Radio-diagnosis, Dayanand Medical College & Hospital, Ludhiana.

METHOD OF COLLECTION OF DATA

This study was conducted over a period of one and half year from 15th September 2022 to 15th March 2024 on 42 patients with clinical evidence of bile duct injury referred for MRCP to the Department of Radio-diagnosis, Dayanand Medical College & Hospital, Ludhiana. Informed Consent was obtained from all patients/guardians and relevant detailed history was elicited. Findings of general physical and systemic examination were recorded. Before starting the study, the procedure was explained to the patient in his/her vernacular language to allay the fear and anxiety. MRCP was performed on Siemens 3T MRI machine.

IMAGE INTERPRETATION AND DEFINITIONS

MR images were assessed for bile duct injuries which can be transection injury which is either partial or complete, biliary occlusion or stricture and bile leak. Contrast enhanced MR images were further assessed for extravasation of contrast from bile duct citing a leak and biliary occlusion or stricture.

Transection injury- Bile duct interruption with associated free fluid or localized fluid collection (biloma).

Biliary occlusion or stricture - Focal tightening, narrowing or abrupt duct interruption with associated upstream biliary dilatation.

Bile leak- Abnormal collection of fluid in close approximation to bile duct.

On contrast enhanced MRCP, non opacification of a narrowed segment of bile duct in an otherwise opacified biliary system is termed as biliary occlusion or stricture.

Active leak of hepatobiliary contrast material outside of biliary tree or increase in signal intensity in an intrahepatic or perihepatic fluid collection is termed as extravasation of contrast.

Inclusion Criteria

All patients with clinical evidence of bile duct injury undergoing Magnetic resonance Cholangiopancreatography.

Exclusion Criterion

1. Anyone who is unwilling to participate in the study.
2. Patients who are already operated upon for bile duct injuries.

MR imaging technique

All patients underwent a multiplanar, multi-sequential MR imaging of upper abdomen on a MAGNETOM SKYRA 48 Channel 3 Tesla MRI Scanner by Siemens, Germany.

Following MR imaging sequences to be included:

1. T2 haste axial
2. T2 haste fat sat axial
3. T2 haste coronal
4. T2 trufi axial
5. T1 VIBE in-out phase axial
6. Diffusion Weighted Imaging(DWI) in axial plane acquired at 3 b-values of 50, 400, 800.
7. T2 TSE 3D coronal.
8. Contrast Enhanced MRI

Contrast Enhanced MRI was performed using three-dimensional volume interpolated breath hold examination (3D VIBE) sequence in the transverse plane.

A rapid bolus of 0.1mmol/kg body weight gadobenate dimeglumine was given through a peripheral vein followed by 10 ml of saline. Images were acquired in arterial, portal and venous phase. Delayed phase images (1 hour after contrast administration) were also acquired. Multiple acquisitions were done till 8 hours of contrast administration. If there was no excretion of the contrast at 8 hours, no further acquisitions were done.

Table 1: MRI Acquisition Parameters

	TR	TE	FOV (R)	FOV (P)	SLICE	SLICE THICK	GAP	FLIP ANGLE	FAT SAT	MATRIX	FLOW COMP	PHASE ENC	ORIENTATION
T1 vibe Fat Sat	3.31 ms	1.3 ms	380 mm	81.3%	72	3 mm	1.1 mm	9^0	SPAIR	182*320	NO	AP	Transverse
T1 vibe In-out phase	4.34 ms	1.34, 2.76 ms	380 mm	81.3%	72	3 mm	1.1 mm	9^0	NONE	182*320	NO	AP	Transverse
T2 haste fat sat	2000 ms	91 ms	350 mm	78.1%	30	5 mm	2.5 mm	160^0	SPAIR	200*320	NO	AP	Transverse
T2 haste traction	2000 ms	91 ms	360 mm	78.1%	30	5 mm	2.5 mm	160^0	NONE	200*320	NO	AP	Transverse
T2 haste coronal	2000 ms	91 ms	350 mm	100%	35	5 mm	0.5 mm	160^0	NONE	288*320	NO	R-L	Coronal
T2 haste thick slab	4500 ms	734 ms	260 mm	100%	1	50 mm	2.5 mm	180^0	FATSAT	314*448	NO	R-L	
Diffusion	5700 ms	48 ms	380 mm	80.6%	30	5 mm	2.5 mm		SPAIR	108*134		AP	Transverse
T2 TSE 3D CORONAL	1600 ms	623 ms	335 mm	100 %	64	1.5 mm	0 mm	180^0	NONE	320*320	NO	R-L	Coronal

T2 haste coronal thin slab	2000 ms	101 ms	350 mm	100%	30	3 mm	0.2 mm	160^0	SPAIR	205*256	NO	R-L	Coronal
T2 Trufi Axial	382 ms	1.68 ms	380 mm	80.5%	30	5 mm	2.5	50^0	None	206*256		AP	Transverse

OUTCOME: Utility of MRCP in assessing bile duct injuries and its role in clinical management.

STATISTICAL ANALYSIS: Data were described in terms of range; mean ±standard deviation (± SD), frequencies (number of cases) and relative frequencies (percentages) as appropriate. Sensitivity, specificity and accuracy of each method and its confidence interval (95% CI) were also determined. A probability value (*p* value) less than 0.05 was considered statistically significant. . All statistical calculations were done using (Statistical Package for the Social Science) SPSS 21.0 version (SPSS Inc., Chicago, IL, USA) statistical program for Microsoft Windows.

OBSERVATIONS & RESULTS

Demographics

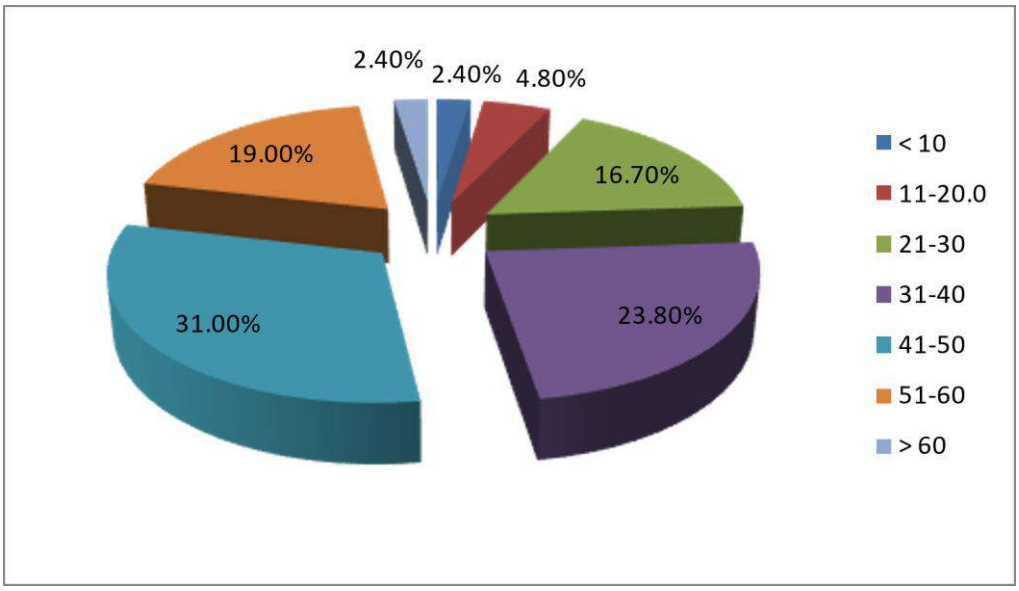
Age

The mean age of the patients was 44.60±16.87 years with an age range of 3-74 years. In the study group, 13 (31%) patients belonged to the age group 41-50 years ,10 (23.8%) patients belonged to age group 31-40, 8 (19%) patients belonged to the age group of 51-60 years, 7 patients belonged to age group of 21- 30 years, 2 patients belonged to the age group of 11-20 years, 1 patient belonged to age group <10 years and 1 patient belonged to age group >60 years. (Refer Table 2, Figure 1)

Table 2 – Distribution of age (years) of study subjects

Age Group	No of cases	Percentage
< 10	1	2.4%
11-20.0	2	4.8%
21-30	7	16.7%
31-40	10	23.8%
41-50	13	31.0%
51-60	8	19.0%
> 60	1	2.4%
Total	42	100.0%

Figure 1 – Distribution of study subjects on the basis of age.



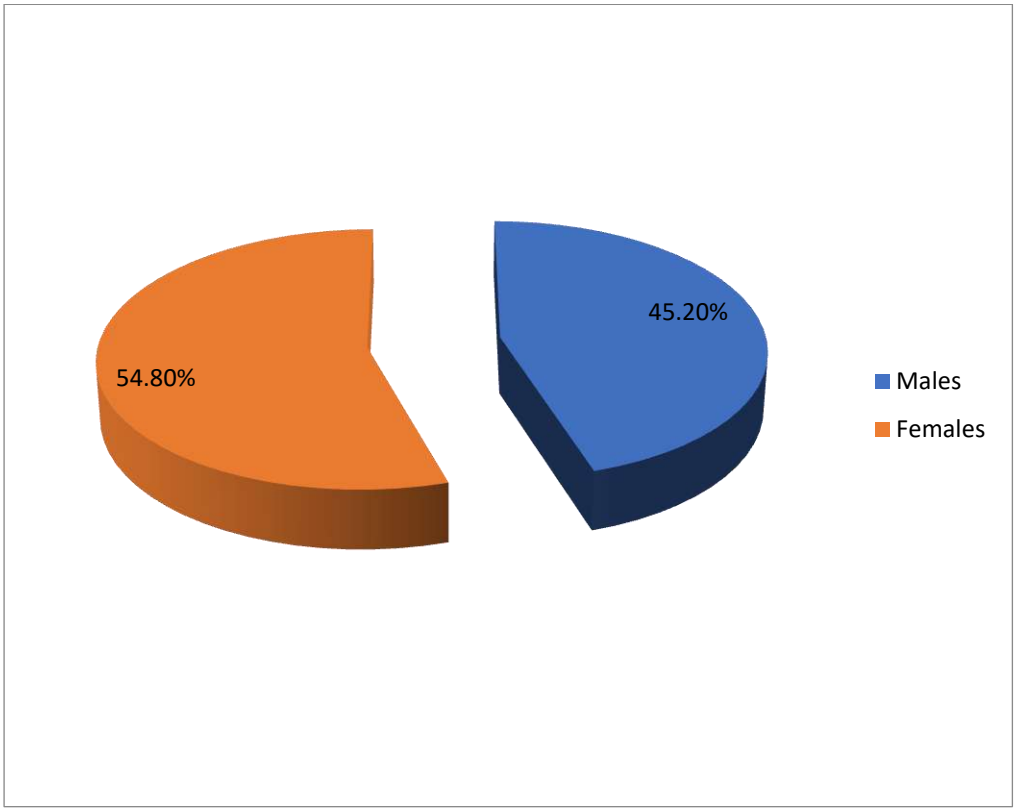
Gender

There were 19(45.2%) males and 23(54.8%) were females in our cohort .(Refer Table 3, Figure 2)

Table 3 –Distribution of various study subjects on the basis of gender

Sex	No. of cases	Percentage
Males	19	45.2%
Females	23	54.8%
Total	42	100.0%

Figure 2 – Distribution of study subjects based on gender.



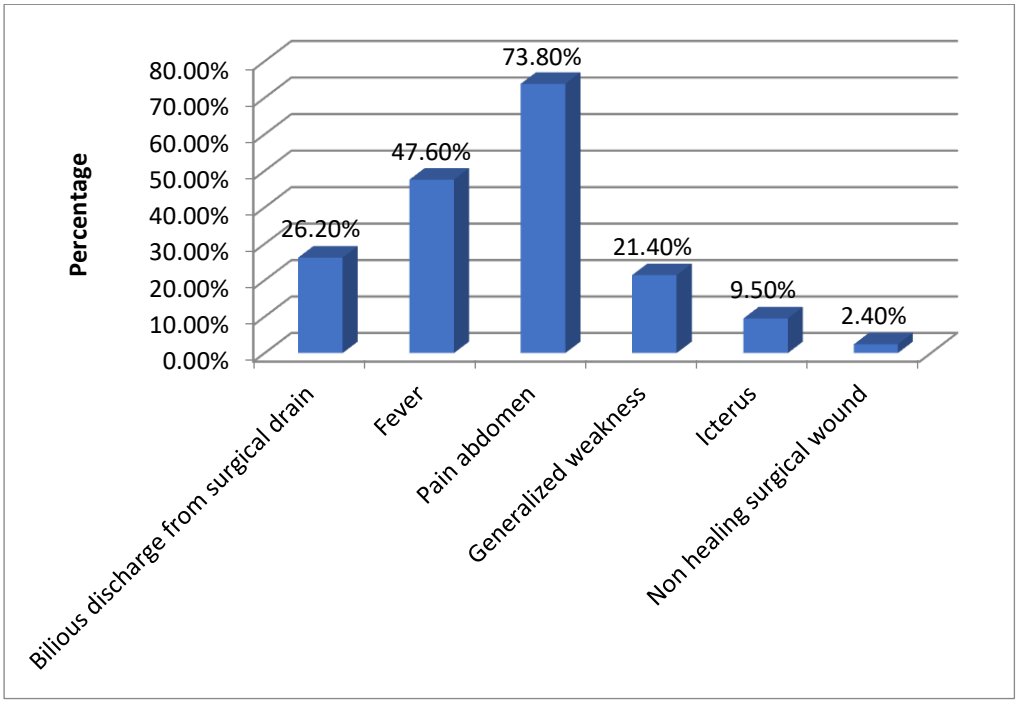
Clinical symptomatology

Pain abdomen was the most common presenting symptom observed in 31(73.8%) subjects followed by fever in 20(47.6%) subjects. 11(26.2%) out of 42 patients had bilious discharge from the surgical drain,9 (21.4%) patients complained of generalized weakness, 4(9.5%) patients had icterus, and 1 (2.4%) patients had non healing surgical wound (Refer Table 4, Figure 3).

Table – 4 Clinical symptomatology and distribution:

Clinical symptomatology	No. of cases	Percentage
Bilious discharge from surgical drain	11	26.2%
Fever	20	47.6%
Pain abdomen	31	73.8%
Generalized weakness	9	21.4%
Icterus	4	9.5%
Non healing surgical wound	1	2.4%

Figure 3 – Clinical symptomatology of cohort



Lab Parameters

The various lab parameters are as shown in Table-5. The normal range for serum Alkaline phosphatase(ALP) is 30-130 IU/L. In our biochemical analysis, 40(95.2%) subjects had deranged ALP as shown in Table-6.

Table 5- Listing various Lab parameters of 42 patients in our study

Parameters	Mean	Std. Deviation	Minimum	Maximum
Haemoglobin	10.17	1.44	7.30	13.80
TLC	13.79	6.58	5.80	37.40
Platelets	344.71	138.12	150.00	591.00
T. Bilirubin	1.21	0.99	0.22	6.10
Direct Bilirubin	0.72	0.88	0.10	5.30
SGOT	45.26	26.45	12.00	115.00
SGPT	47.57	52.24	9.00	351.00
ALP	225.38	78.69	52.00	401.00
Albumin	3.18	0.67	1.70	4.80
Creatinine	0.70	0.38	0.24	2.40
Urea	20.95	18.16	4.00	114.00

Table 6- Distribution of ALP profile

ALP	No. of cases	Percentage
<130	2	4.8%
>130	40	95.2%
Total	42	100.0%

Mechanism of bile duct injuries:

In our study, 37 (88.1%) patients were suspected to have iatrogenic biliary injury while 5 (11.9%) patients had non iatrogenic causes. (Refer Table 7). In the iatrogenic injury group, 28 patients had history of laparoscopic cholecystectomy and 9 patients had history of open cholecystectomy (Refer Table 8).

Table 7 – Mechanism of injury in subjects.

Mechanism of Injury	No. of cases	Percentage
Iatrogenic	37	88.1%
Non – Iatrogenic	5	11.9%
Total	42	100.0%

Table 8- Distribution of the study subjects on the basis of the surgical procedure they underwent:

Surgical Procedure	No. of cases	Percentage
Lap cholecystectomy	28	75.68%
Open cholecystectomy	9	24.32%
Total	37	100.0%

Findings on MRCP

Biliary anatomy

Analysis of MRCP images revealed conventional anatomy in 29 (69%) subjects and variant anatomy was observed in 13 (31 %) subjects . (Refer Table 9, Figure 4).

In the 13 subjects with variant anatomy, right posterior duct draining into CHD was observed in 5 subjects followed by low anteromedial insertion of cystic duct in 2, trifurcation pattern in 2 subjects. Accessory duct draining segment 5 and segment 8 , Right posterior duct draining into the left hepatic duct, Segment 5 duct draining into the right posterior duct, and segment 8 duct draining into the common hepatic duct were observed in one patient each .(Refer Table 10, Figure 5)

Table -9– Distribution on the basis of biliary anatomy

Biliary Anatomy	No. of cases	Percentage
Variant anatomy	13	31.0%
Conventional anatomy	29	69.0%
Total	42	100.0%

Figure 4 – Distribution on the basis of biliary anatomy

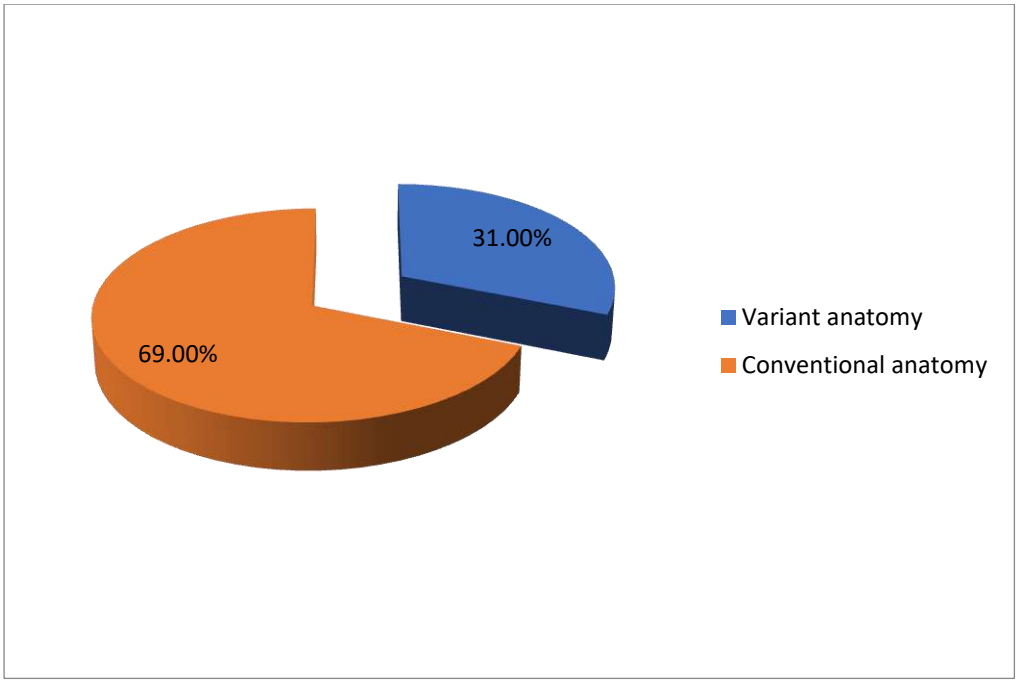
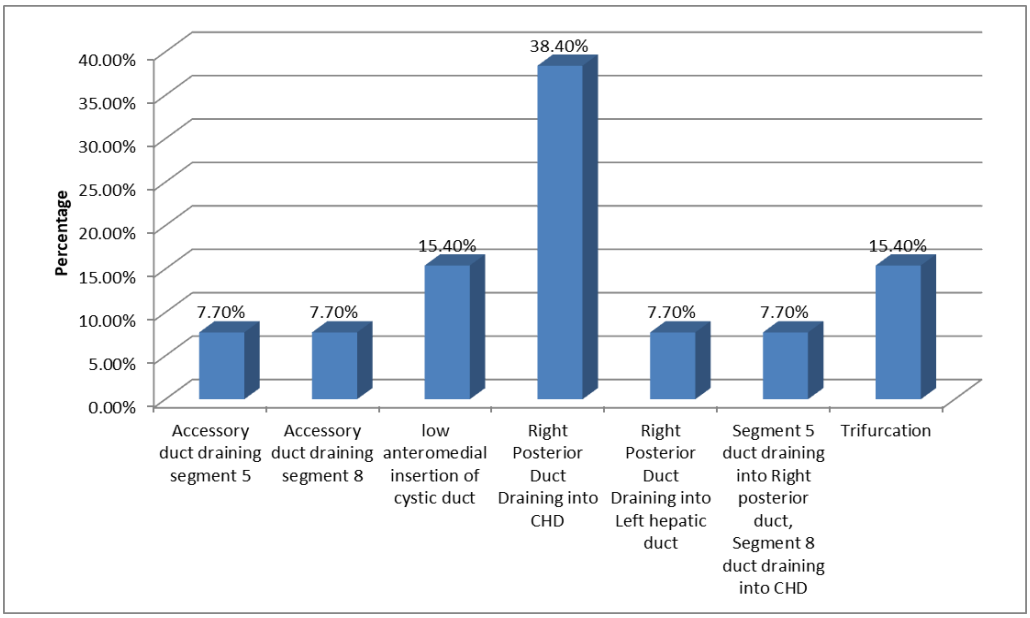


Table 10- variant anatomy observed in our cohort

Variant Anatomy	No. of cases	Percentage
Accessory duct draining segment 5	1	7.7%
Accessory duct draining segment 8	1	7.7%
Low anteromedial insertion of cystic duct	2	15.4%
Right Posterior Duct Draining into CHD	5	38.4%
Right Posterior Duct Draining into Left hepatic duct	1	7.7%
Segment 5 duct draining into Right posterior duct, Segment 8 duct draining into CHD	1	7.7%
Trifurcation	2	15.4%
Total	13	100.0%

Figure 5 – Variant anatomy observed in our cohort



Dilated Intra-hepatic biliary radicals and dilated Common bile duct

Dilated intrahepatic biliary radicals were seen in 9 (21.4%) of the subjects while dilated common bile duct was seen in 3 (7.1%) of the subjects as shown in table-11 and table-12 respectively.

Table 11 – Distribution on the basis on presence of dilated IHBR

Dilated IHBR	No. of cases	Percentage
Yes	9	21.4%
No	33	78.6%
Total	42	100.0%

Table 12 – Distribution of subjects on the basis of presence of dilated CBD

Dilated CBD	No. of cases	Percentage
Yes	3	7.1%
No	39	92.9%
Total	42	100.0%

Free fluid

In Our cohort, 7 (16.7%) subjects were found to have free fluid on MRCP as shown in table-13

Table-13 Distribution of the study subjects on the basis of the presence of free fluid

Free Fluid	No. of cases	Percentage
Yes	7	16.7%
No	35	83.3%
Total	42	100.0%

Biloma formation

In our analysis , Biloma formation was observed in 31(73.8%) subjects on MRCP.(Refer Table 14)

Table 14 – Distribution of various study subjects on the basis of biloma formation

Biloma formation	**No. of cases**	**Percentage**
Yes	31	73.8%
No	11	26.2%
Total	42	100.0%

Findings on non-contrast MRCP

On Analysis of non- contrast MRCP, 23(54.8%) subjects were reported to have bile duct injuries (Refer Table 15). Of various patients who had bile duct injuries, 16 patients had bile leak, 5 patients had biliary strictures and 2 patients had cystic duct leak (Refer Table 16, Figure 6).

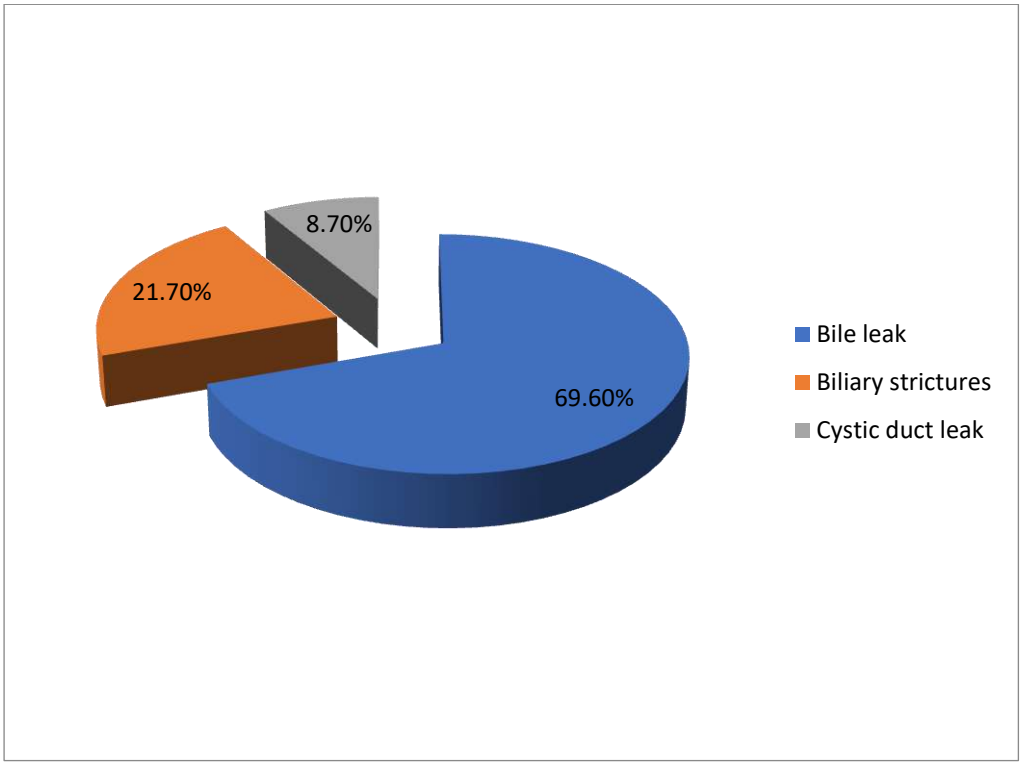
Table 15- Distribution of the study subjects on the basis of the presence of bile duct injury.

Bile duct Injury on non contrast MRCP	No. of cases	Percentage
Present	23	54.8%
Absent	19	45.2%
Total	42	100.0%

Table 16- Various types of the bile duct injuries observed

Bile duct injury	No of cases	Percentage
Bile leak	16	69.6%
Biliary strictures	5	21.7%
Cystic duct leak	2	8.7%
Total	23	100%

Figure 6 - Various types of the bile duct injuries observed



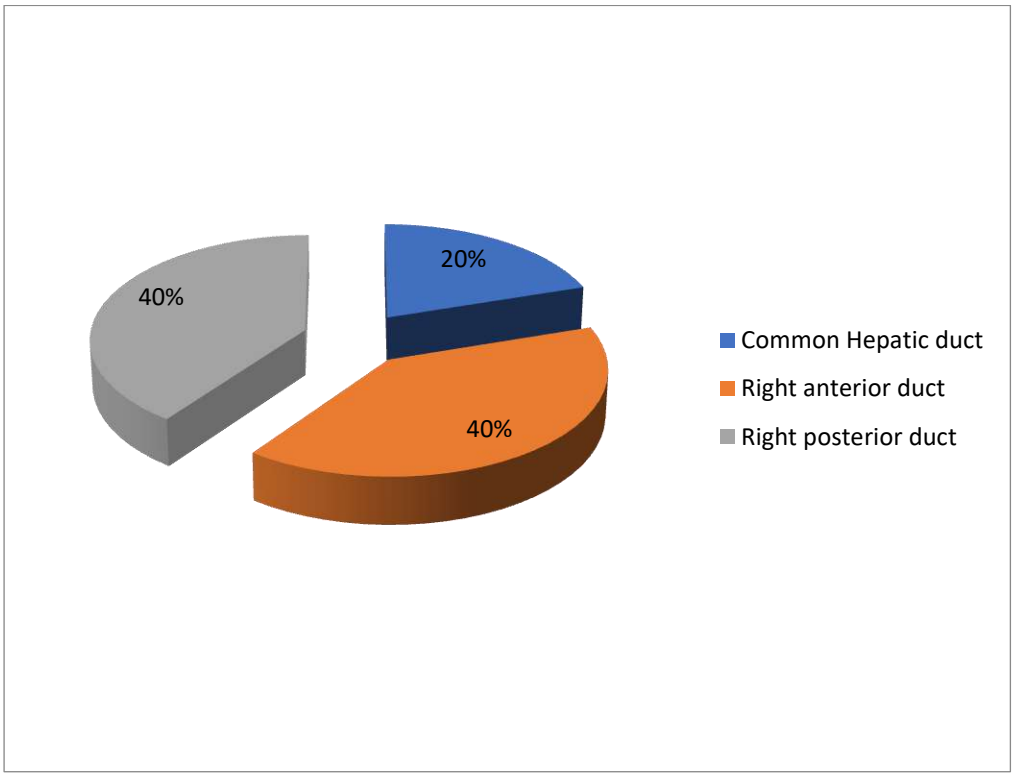
Biliary strictures

In our analysis, 5 (21.7%) subjects had biliary strictures visible on MRCP. The location of strictures was common hepatic duct in one patient, two patients each had right anterior and right posterior ductal injury (Refer Table 17, Figure 7) .

Table – 17 Site of the biliary strictures

Site of Biliary Stricture	No. of cases	Percentage
Common Hepatic duct	1	20%
Right anterior duct	2	40%
Right posterior duct	2	40%
Total	5	100%

Figure 7- Site of the biliary strictures



Transection of the bile duct

Transection of the bile duct was observed in 16 (38.1%) subjects. Injury to the common hepatic duct was observed in 3 patients, 3 subjects had injury involving the right posterior duct, 2 subjects had transection at common hepatic duct and primary confluence. Involvement of the Right anterior duct, right hepatic duct and combined suprapancreatic common bile duct and common hepatic duct injury was observed in 2 patients each. Isolated transection of common bile duct and segment V duct was observed in one patient in each group (Refer Table 18 and 19, Figure 8).

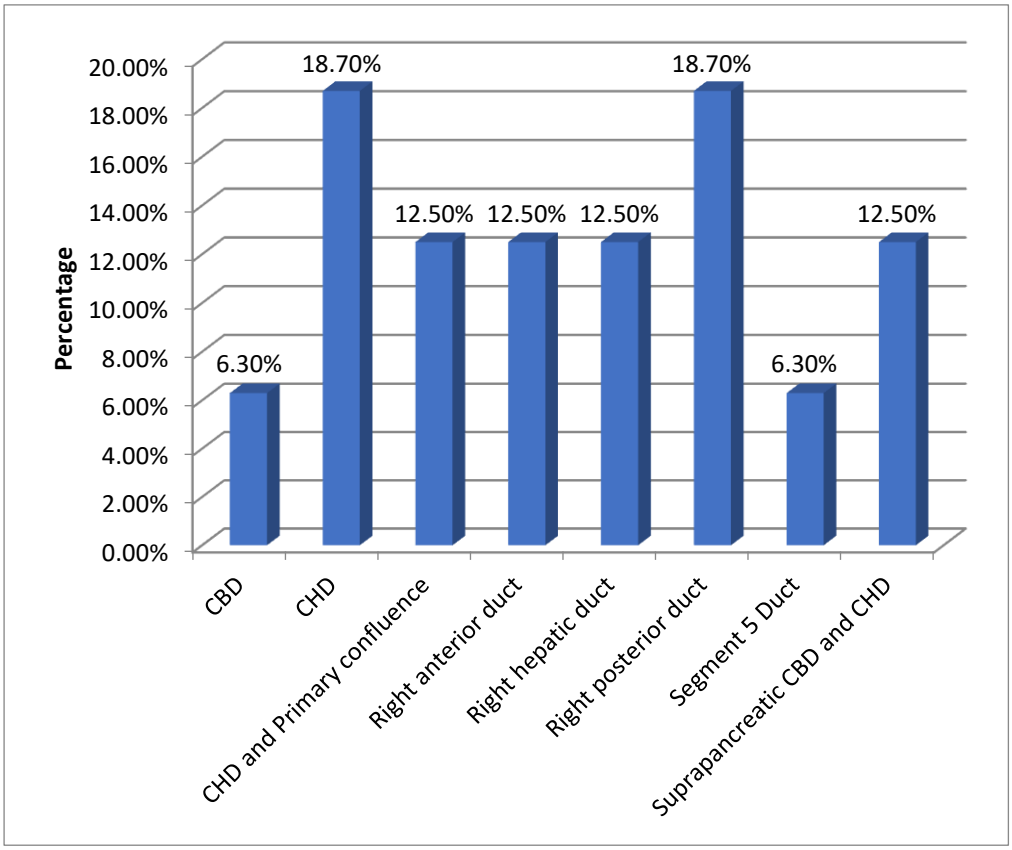
Table 18- Transection of the bile duct

Transection of Bile Duct	No. of cases	Percentage
Yes	16	38.1%
No	26	61.9%
Total	42	100.0%

Table 19 – Duct involvement in transection injury

Bile Duct involved in Transection injury	No. of cases	Percentage
CBD	1	6.3%
CHD	3	18.7%
CHD and Primary confluence	2	12.5%
Right anterior duct	2	12.5%
Right hepatic duct	2	12.5%
Right posterior duct	3	18.7%
Segment 5 Duct	1	6.3%
Suprapancreatic CBD and CHD	2	12.5%
Total	16	100.0%

Figure 8 - Duct involvement in transection injury



Finding on contrast-enhanced MRCP

All 42 patients were given intravenous contrast in the form of Gadobenate dimeglumine (MultiHance). Analysis of contrast enhanced MRCP images revealed bile duct injury in 29(69%) subjects. Analysis revealed 21(72.4%) patients had extravasation of contrast from bile duct, 6(20.7%) patients had extravasation from cystic duct and 2(6.9%) patients had biliary occlusion (Refer table 20 and 21) .

Table 20- Distribution of various study subjects on the basis of presence or absence of bile duct injuries.

Bile duct injury on Contrast MRCP	No. of cases	Percentage
Present	29	69.0%
Absent	13	31.0%
Total	42	100.0%

Table 21- Type of biliary injuries

Type of bile duct injury	No of cases	Percentage
Extravasation from bile duct	21	72.4%
Extravasation from cystic duct	6	20.7%
Biliary occlusion	2	6.9%
Total	29	100%

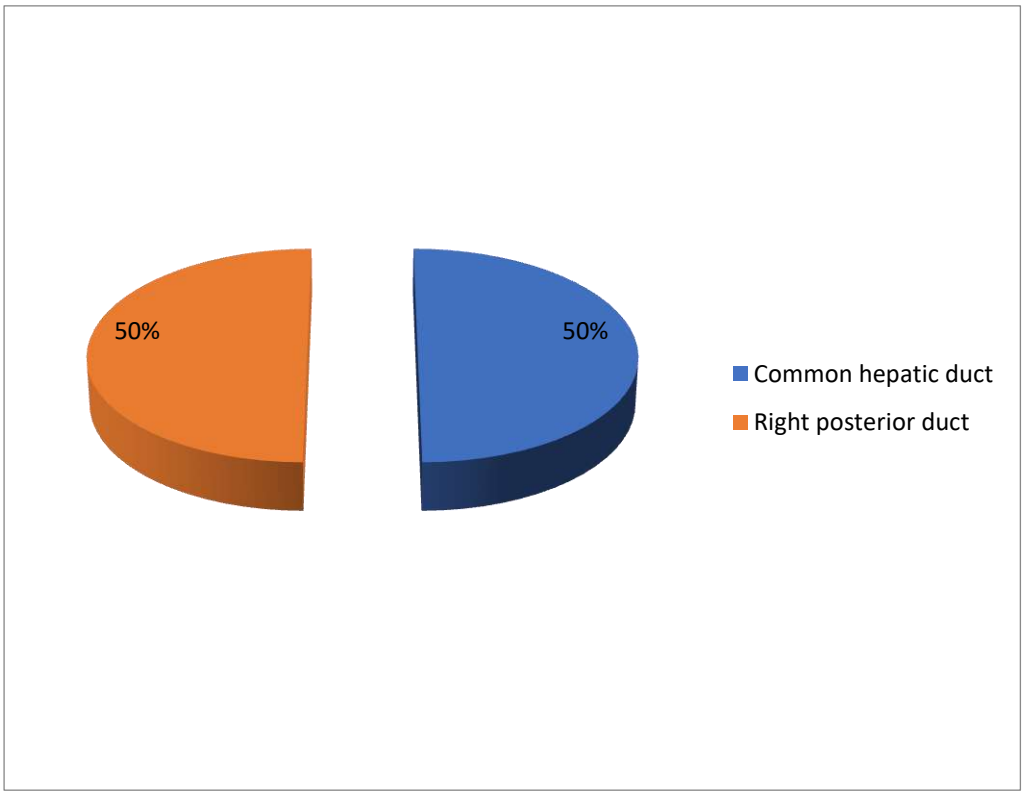
Biliary occlusion

On contrast enhanced MRCP, 2 patients were noted to have biliary stricture involving common hepatic duct and right posterior duct respectively (Table 22, Figure 9).

Table 22- Bile duct involved in biliary occlusion on contrast enhanced MRCP

Bile Duct involved in biliary occlusion	No of cases	Percentage
Common hepatic duct	1	50%
Right posterior duct	1	50%
Total	2	100%

Figure 9- Bile duct involved in biliary occlusion on contrast enhanced MRCP



Findings on Combined Non – contrast and Contrast enhanced MRCP

On combined evaluation using non contrast and contrast enhanced MRCP, 33 (78.6%) patients were reported to have bile duct injury. Subanalysis revealed 23(69.7%) patients had bile leak, 7(21.2%) had cystic duct leak and 3(9.1%) had biliary strictures. Two patients were noted to have biliary stricture at right anterior duct and right posterior duct on non-contrast MRCP but adequate opacification of the above-mentioned ducts was achieved on contrast enhanced MRCP(Refer Table 23 and 24, Figure 10) .

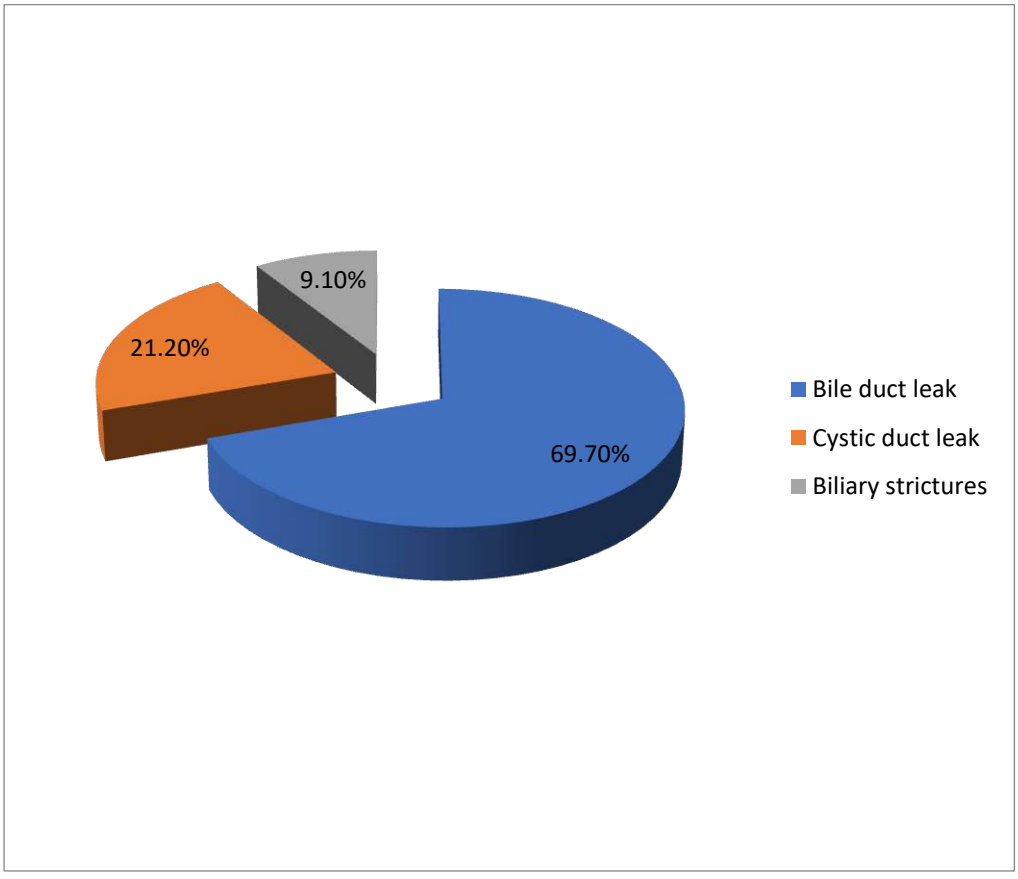
Table 23- Distribution of the patients on the basis of bile duct injury on non-contrast and contrast enhanced MRCP

Bile duct injury on non-contrast and contrast MRCP	**No. of cases**	**Percentage**
Absent	9	21.4%
Present	33	78.6%
Total	42	100.0%

Table 24- Various types of bile duct injuries reported on non-contrast and contrast MRCP

Bile duct injury on non contrast and contrast MRCP	No of cases	Percentage
Bile duct leak	23	69.7%
Cystic duct leak	7	21.2%
Biliary strictures	3	9.1%
Total	33	100%

Figure 10- Various types of bile duct injuries reported on non-contrast and contrast MRCP



Transection of hepatic duct

Amongst various patients, 23 subjects were identified with hepatic duct transections on combined non-contrast and contrast enhanced MRCP. Subgroup analysis revealed that the common hepatic duct and right posterior duct were transected in 4(17.5%) subjects each. Common hepatic duct and primary confluence, suprapancreatic common bile duct and common hepatic duct, right anterior duct, right hepatic duct and duct draining segment 5 were transected in 2(8.7%) subjects each. Common bile duct, left hepatic duct, lateral branch of left hepatic duct, medial branch of left hepatic duct and Accessory duct draining segment 8 was transected in 1(4.3%) subject each.(Refer Table 25 and 26, Figure 11)

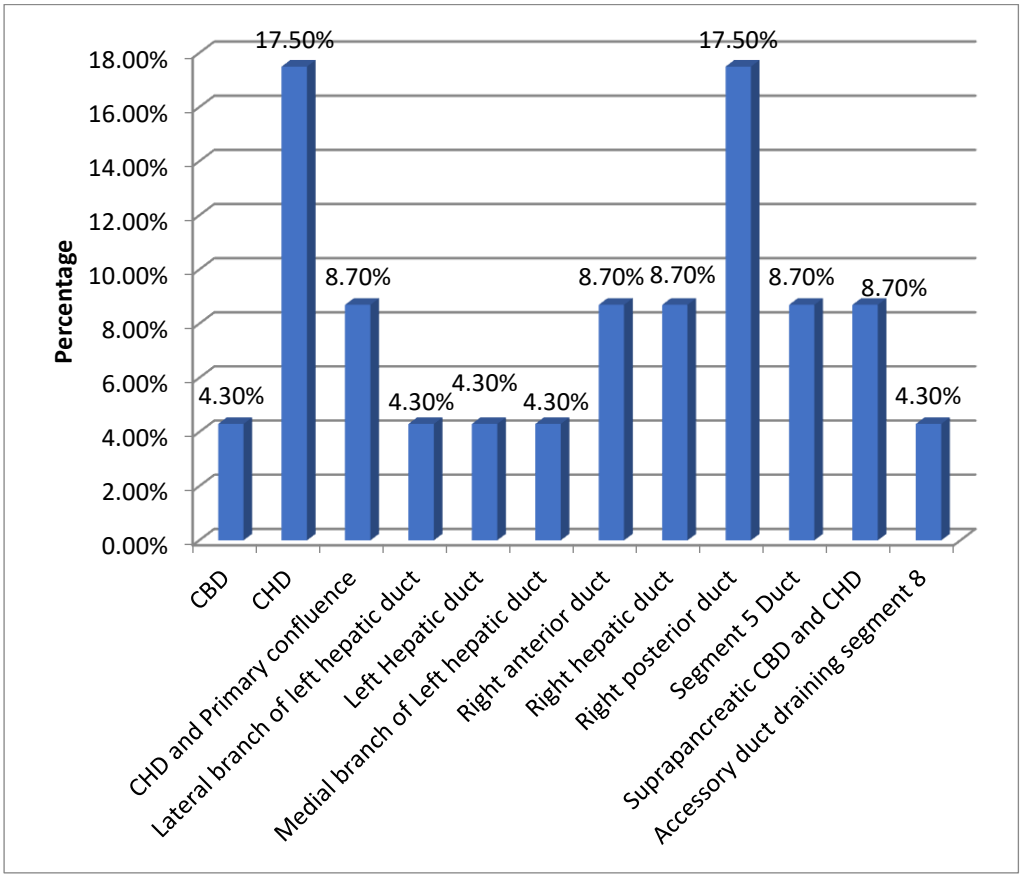
Table 25- Distribution of the patients on the basis of transection of bile duct on non-contrast and contrast enhanced MRCP

Transection of Bile duct (Non contrast and Contrast enhanced MRCP)	**No. of cases**	**Percentage**
Yes	23	54.8%
No	19	45.2%
Total	42	100.0%

Table 26- Duct involved in transection of bile duct on combined non contrast and contrast enhanced MRCP.

Duct involved in transection of bile duct	No. of cases	Percentage
CBD	1	4.3%
CHD	4	17.5%
CHD and Primary confluence	2	8.7%
Lateral branch of left hepatic duct	1	4.3%
Left Hepatic duct	1	4.3%
Medial branch of Left hepatic duct	1	4.3%
Right anterior duct	2	8.7%
Right hepatic duct	2	8.7%
Right posterior duct	4	17.5%
Segment 5 Duct	2	8.7%
Supra pancreatic CBD and CHD	2	8.7%
Accessory duct draining segment 8	1	4.3%
Total	23	100.0%

Figure 11- Duct involved in transection of bile duct on combined non contrast and contrast enhanced MRCP.



Intervention

Endoscopic interventions were performed in 20 (47.6%) patients while 22 (52.4%) patients underwent a surgical intervention. In the ERCP group, 2 (4.8%) patients underwent diagnostic ERCP and 18(95.2%) underwent therapeutic and diagnostic ERCP. Amongst the 18 patients who underwent therapeutic and diagnostic ERCP,15(35.7%) patients underwent CBD stenting and sphincterotomy procedure and 3(7.1%) patients underwent LHD stenting and sphincterotomy procedure.

In the surgery group, hepaticojejunostomy was performed in 17 (77.3%) patients while diagnostic laparoscopy was performed in remainder 5 (22.7%) patients (Table 27, 28, 29 Figure 12 and 13).

Table 27- Types of interventions.

Intervention	No. of cases	Percentage
ERCP	20	47.6%
Surgery	22	52.4%
Total	42	100.0%

Table 28- Distribution of patients who underwent ERCP

ERCP	No. of cases	Percentage
CBD Stenting and Sphincterotomy	15	35.7%
Diagnostic ERCP	2	4.8%
LHD Stenting and Sphincterotomy	3	7.1%
Total	20	100.0%

Figure 12- Distribution of patients who underwent ERCP

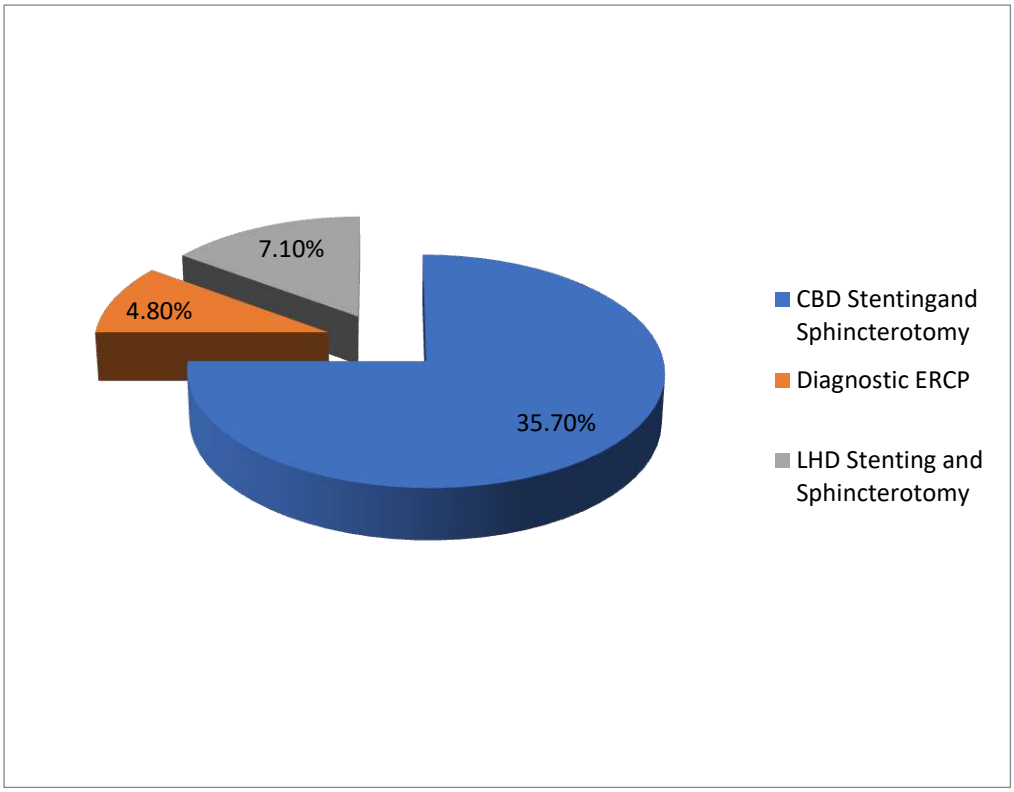
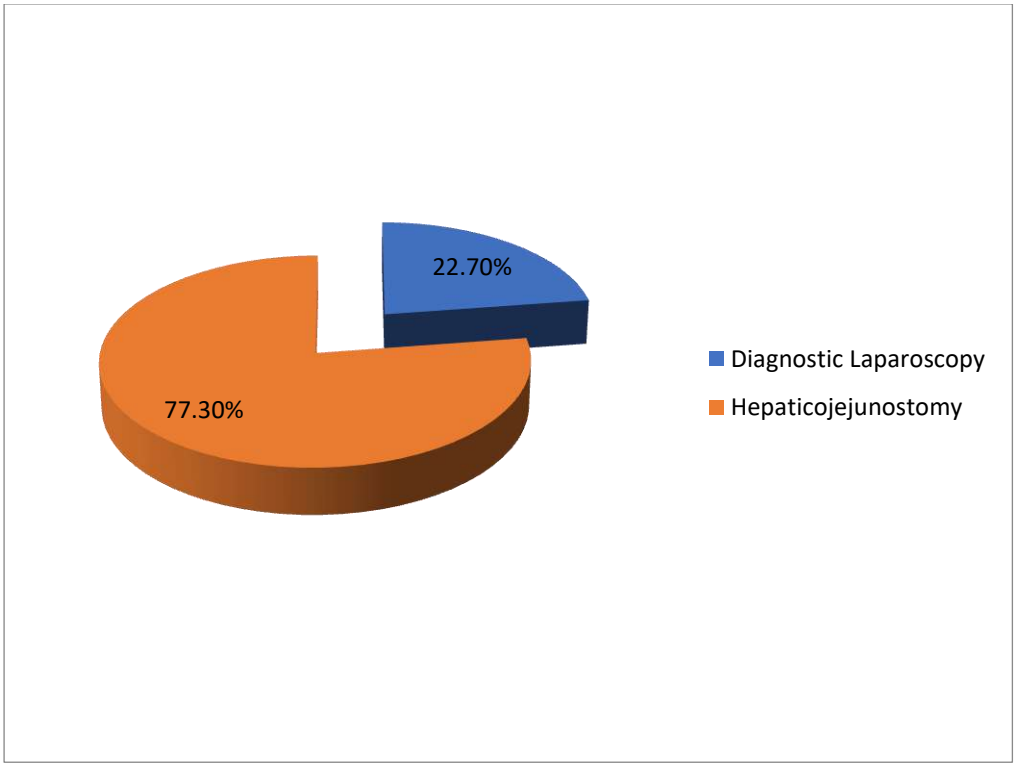


Table 29- Distribution of patients who underwent surgery.

Surgery	No. of cases	Percentage
Diagnostic Laparoscopy	5	22.7%
Hepaticojejunostomy	17	77.3%
Total	22	100.0%

Figure 13- Distribution of patients who underwent surgery.

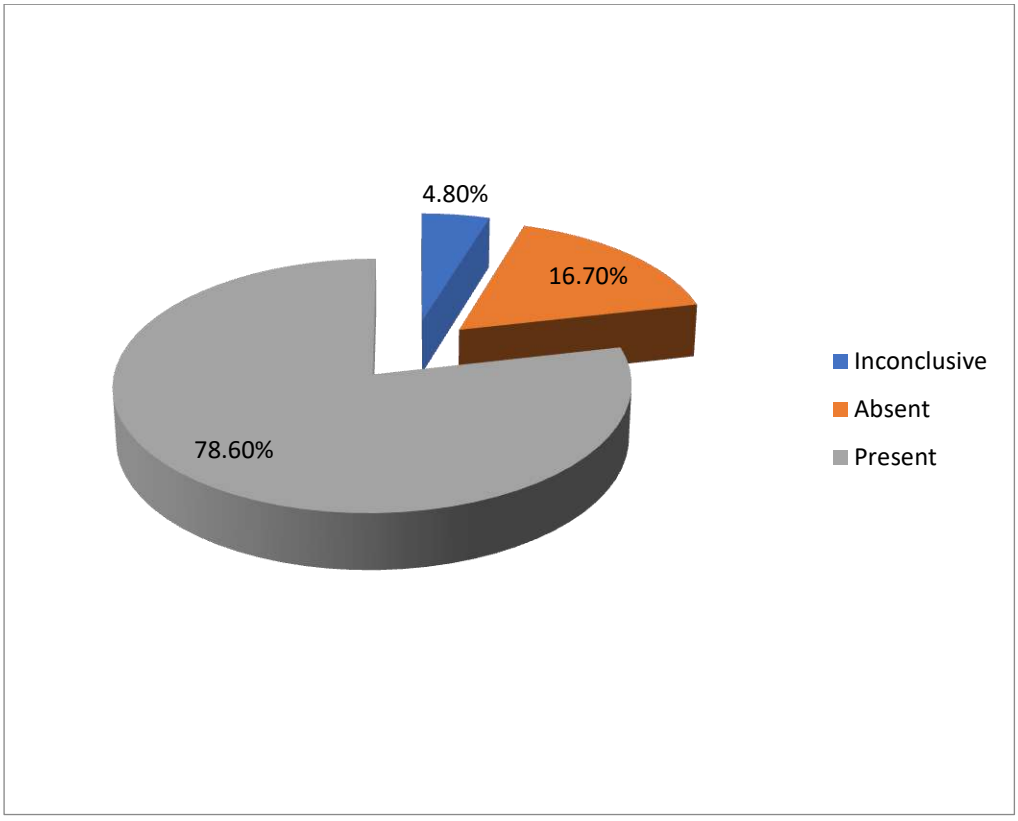


Post surgery/ERCP ,out of 42 patients, bile duct injury was found in 33(78.6%) patients, was absent in 7(16.7%) patients and in 2(4.8%) results were declared inconclusive .(Table 30, Figure 14)

Table 30- Distribution of the patients on the basis of bile duct injury on Surgery/ERCP

Bile duct Injury on Surgery/ERCP	No. of cases	Percentage
Inconclusive	2	4.8%
Absent	7	16.7%
Present	33	78.6%
Total	42	100%

Figure 14 – Distribution of the patients on the basis of bile duct injury on Surgery/ERCP



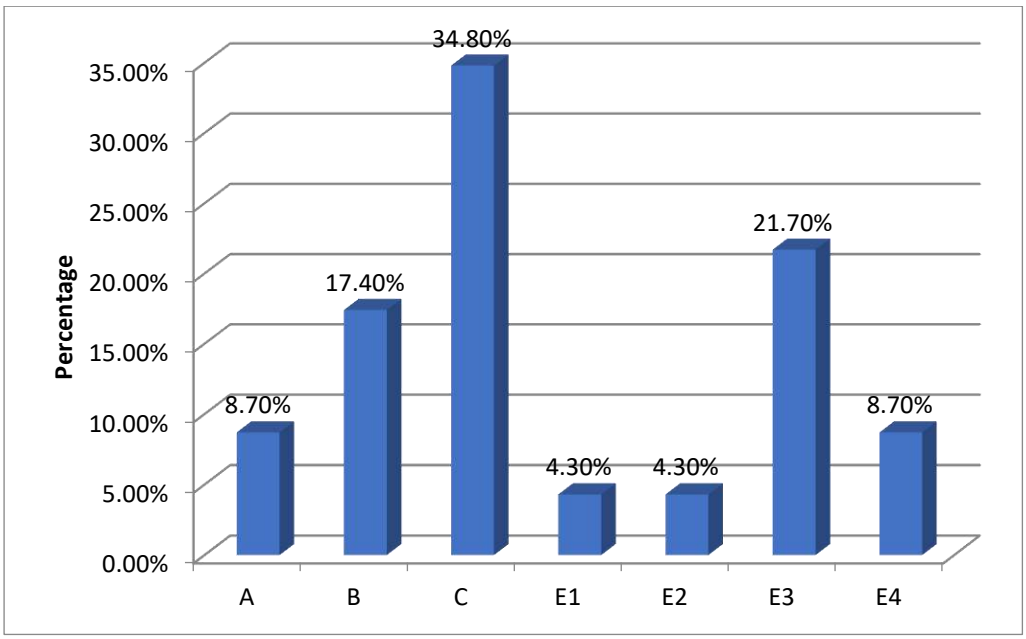
Strasberg Classification: A Comparison

On classifying injuries according to the Strasberg classification in 23 patients with injury on non-contrast MRCP, Type C injury was observed in 8 (34.8%) patients while Type E3 injury was encountered in 5 (21.7%) patients. Type B injury was detected in 4 (17.4%) patients. Type A and E4 injuries were observed in 2 (8.7%) patients each while Type E1 and E2 injury was present in 1(4.3%) patient each.(Refer Table 31, Figure 15)

Table 31- Strasberg classification based on non-contrast MRCP

Classification on Non - contrast MRCP	No. of cases	Percentage
A	2	8.7%
B	4	17.4%
C	8	34.8%
E1	1	4.3%
E2	1	4.3%
E3	5	21.7%
E4	2	8.7%
Total	23	100.0%

Figure 15- Strasberg classification based on non-contrast MRCP

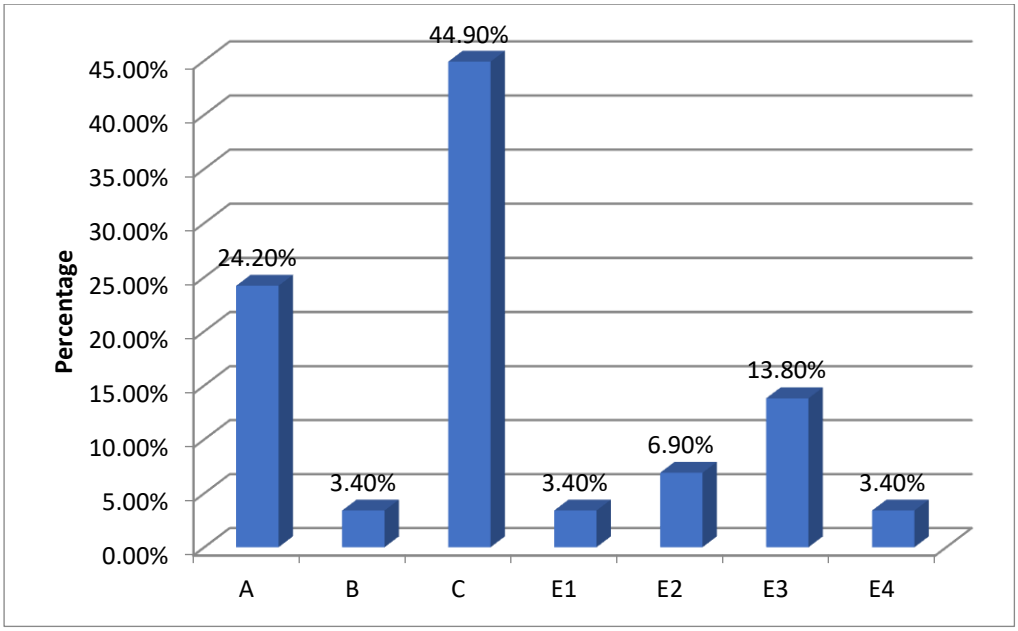


On Analysis of contrast enhanced MRCP, 29 patients with bile duct injuries were detected and type A injury was observed in 7(24.2%) patients. Type C injury in 13 (44.9%), while type E2 injury was observed in 2 (6.9%) patients. Type E3 injury was encountered in four patients (13.8%). Type B, E1 and E4 injuries were observed in one patient (3.4%) each. (Table 32, Figure 16)

Table-32 Strasberg classification based on contrast enhanced MRCP

Classification on Contrast enhanced MRCP	No. of cases	Percentage
A	7	24.2%
B	1	3.4%
C	13	44.9%
E1	1	3.4%
E2	2	6.9%
E3	4	13.8%
E4	1	3.4%
Total	29	100.0%

Figure 16- Strasberg classification based on contrast enhanced MRCP

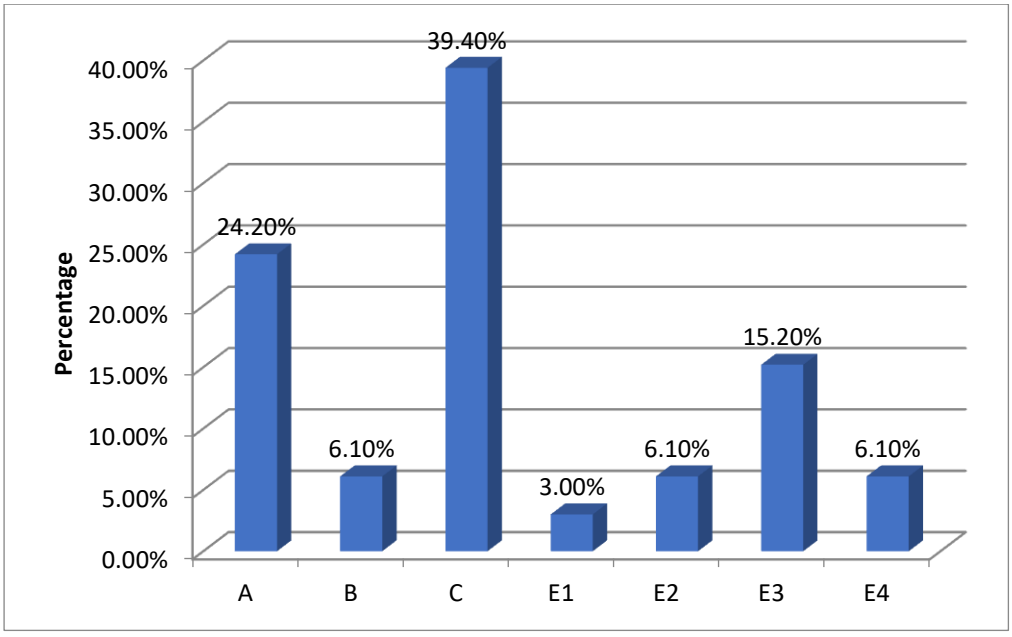


Combination of non-contrast and contrast enhanced MRCP revealed injuries in 33 patients, Amongst these patients, subgroup analysis revealed type A injury in 8(24.2%) patients. Type C injury in 13(39.4%),5(15.2%) patients had type E3 injury and type E1 injury was observed in 1(3%) patient. Type B, E2 and E4 injuries were encountered in 2(6.1%) patients each.(Refer Table 33, Figure 17)

Table -33 Distribution of various bile duct injuries classified on combined non contrast and contrast enhanced MRCP

Classification on combined non contrast and contrast MRCP	No. of cases	Percentage
A	8	24.2%
B	2	6.1%
C	13	39.4%
E1	1	3.0%
E2	2	6.1%
E3	5	15.2%
E4	2	6.1%
Total	33	100.0%

Figure 17- Distribution of various bile duct injuries classified on combined non contrast and contrast enhanced MRCP

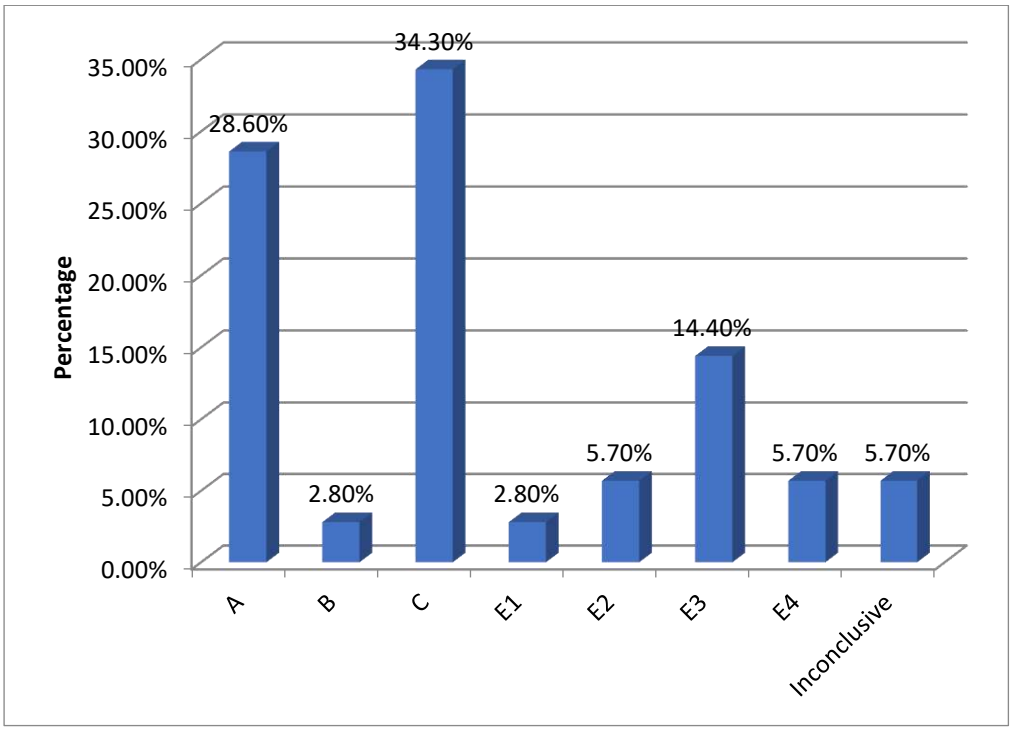


Amongst the 42 patients, bile duct injury was not detected in 7 patients during either ERCP or surgery. In rest of the 35 patients, Type A injury was detected in 10(28.6%) patients, 12(34.3%) patients had type C injury, 5(14.4%) patients had type E3 injury while type E2 and E4 injuries were observed in 2(5.7%) patients each. Type B and E1 injuries were found in 1(2.8%) patient each. 2 examinations were rendered inconclusive on ERCP , while combined non contrast and contrast enhanced MRCP reported these injuries in Segment 5 duct and right anterior duct as ERCP procedure could only visualize the ducts till the secondary confluence in these patients.(Refer Table 34, Figure 18)

Table-34 Strasberg classification based on ERCP or Surgery.

Strasberg classification on basis of Surgical/ERCP findings	No. of cases	Percentage
A	10	28.6%
B	1	2.8%
C	12	34.3%
E1	1	2.8%
E2	2	5.7%
E3	5	14.4%
E4	2	5.7%
Inconclusive	2	5.7%
Total	35	100.0%

Figure 18- Strasberg classification based on ERCP or Surgery.



Non-contrast MRCP findings were consistent with surgical or ERCP findings in 25 patients. In two patients with inconclusive ERCP results, non-contrast MRCP identified a type B injury in one patient and no injury in the other. Five patients showed no bile duct injury on both non-contrast MRCP and surgery/ERCP. These five patients were taken up for surgery/ERCP as they were having consistent clinical symptoms and deranged LFTs. Non-contrast MRCP reported type B injuries (biliary strictures at the right anterior and right posterior ducts) in two patients, which were not confirmed by surgery/ERCP.

Amongst the 10 patients identified with type A injury by surgery/ERCP, non-contrast MRCP detected the same injury in 2 patients, while the rest were found to have no injury. Both type B and E1 injuries were detected in one patient each by both surgery and non-contrast MRCP. Out of 12 patients with type C injury identified by surgery/ERCP, non-contrast MRCP accurately detected the same injury in 8 patients. Non-contrast MRCP detected type E2 injury in 1 out of 2 patients who had such injuries according to surgery/ERCP. Additionally, non-contrast MRCP findings were consistent with surgical/ERCP findings for type E3 injury in 5 patients and type E4 injury in 2 patients.(Refer Table 35 and 36, Figure 19 and 20)

Table 35- Comparison of Various types of bile duct injuries on non-contrast MRCP and Surgery/ERCP.

		Strasberg classification on the basis of surgical/ERCP findings									
		No injury	A	B	C	E1	E2	E3	E4	Inconclusive	Total
Classification on Plain MRCP	No injury	5	8	0	4	0	1	0	0	1	19
	A	0	2	0	0	0	0	0	0	0	2
	B	2	0	1	0	0	0	0	0	1	4
	C	0	0	0	8	0	0	0	0	0	8
	E1	0	0	0	0	1	0	0	0	0	1
	E2	0	0	0	0	0	1	0	0	0	1
	E3	0	0	0	0	0	0	5	0	0	5
	E4	0	0	0	0	0	0	0	2	0	2
	Total	7	10	1	12	1	2	5	2	2	42

Figure 19- Comparison of Various types of bile duct injuries on non-contrast MRCP and Surgery/ERCP.

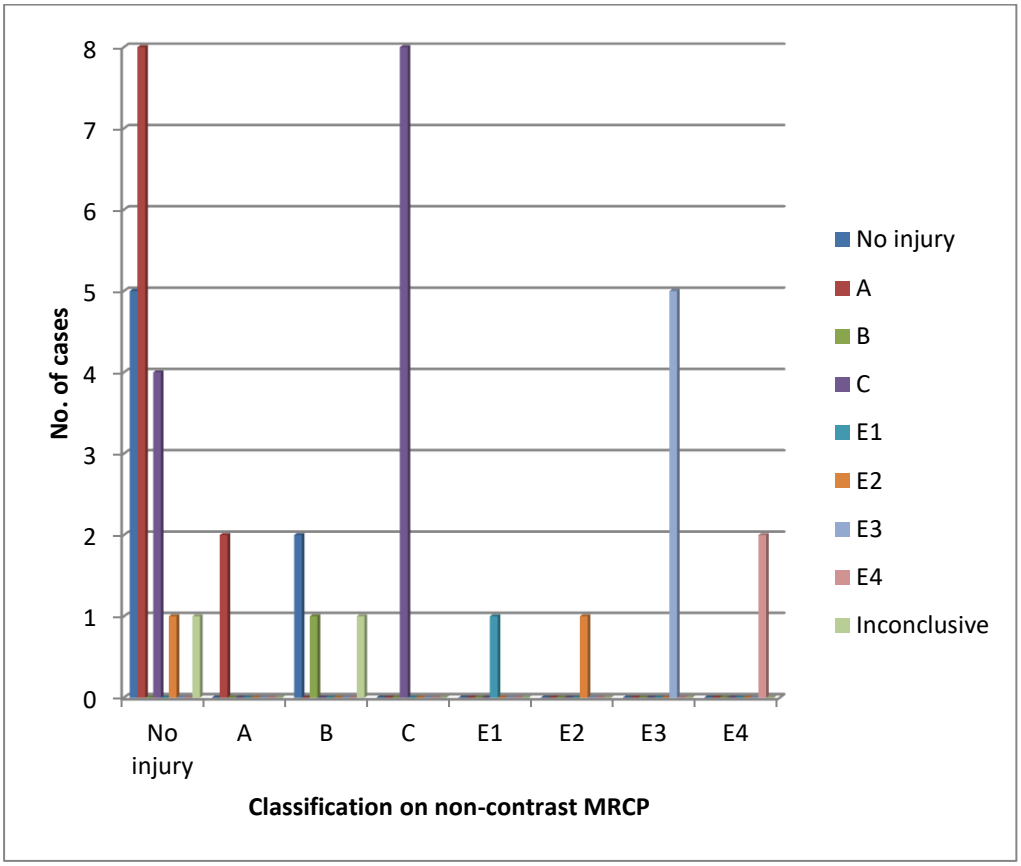
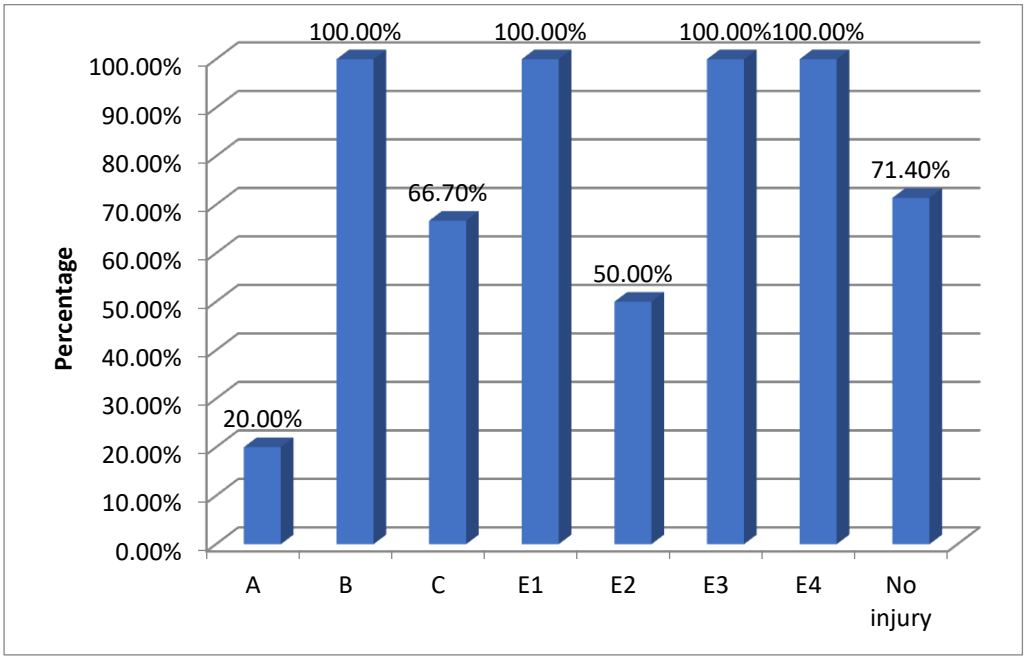


Table 36- Concordance between Plain MRCP and Surgery/ERCP in detecting bile duct injuries (2 patients were excluded as they had inconclusive results on ERCP)

	Strasberg classification on basis of Surgical/ ERCP findings	Classification on Plain MRCP	Concordance
	No. of cases	No. of cases	
A	10	2	20.0%
B	1	1	100.0%
C	12	8	66.7%
E1	1	1	100.0%
E2	2	1	50.0%
E3	5	5	100.0%
E4	2	2	100.0%
No injury	7	5	71.4%
TOTAL	40	25	62.5%

Figure 20- Concordance between non-contrast MRCP and Surgery/ERCP in detecting bile duct injuries (2 patients were excluded as they had inconclusive results on ERCP)



Contrast-enhanced MRCP findings matched the surgical or ERCP findings in 33 cases. Two patients had inconclusive ERCP results ,however, contrast-enhanced MRCP identified a type C injury in one patient and no injury in the other. Six patients showed no bile duct injury on both contrast-enhanced MRCP and surgery/ERCP, while one patient was reported to have a type A injury (accessory duct leak in segment 8 of the liver) on contrast-enhanced MRCP, which was not found during surgery.

Amongst the 10 patients identified with type A injury by surgery/ERCP, contrast-enhanced MRCP detected the same injury in 6 patients, while the rest were found to have no injury. Both type B and E1 injuries were detected in one patient each by both surgery and contrast-enhanced MRCP. Out of 5 patients with type E3 injury identified by surgery/ERCP, contrast-enhanced MRCP accurately detected the same injury in 4 patients. Contrast-enhanced MRCP detected type E4 injury in 1 out of 2 patients who had such injuries according to surgery/ERCP. Additionally, contrast-enhanced MRCP findings were consistent with surgical/ERCP findings for detecting type C injury in 12 patients and type E2 injury in 2 patients.(Table 37 and 38, Figure 21 and 22).

Table 37- Comparison of various types of bile duct injuries detected on contrast enhanced MRCP and Surgery/ERCP.

		Strasberg classification on basis of surgery/ERCP findings									
		No injury	A	B	C	E1	E2	E3	E4	Inconclusive	
Classification on Contrast MRCP	No injury	6	4	0	0	0	0	1	1	1	13
	A	1	6	0	0	0	0	0	0	0	7
	B	0	0	1	0	0	0	0	0	0	1
	C	0	0	0	12	0	0	0	0	1	13
	E1	0	0	0	0	1	0	0	0	0	1
	E2	0	0	0	0	0	2	0	0	0	2
	E3	0	0	0	0	0	0	4	0	0	4
	E4	0	0	0	0	0	0	0	1	0	1
Total		7	10	1	12	1	2	5	2	2	42

Figure 21- comparison of various types of bile duct injuries detected on contrast enhanced MRCP and Surgery/ERCP.

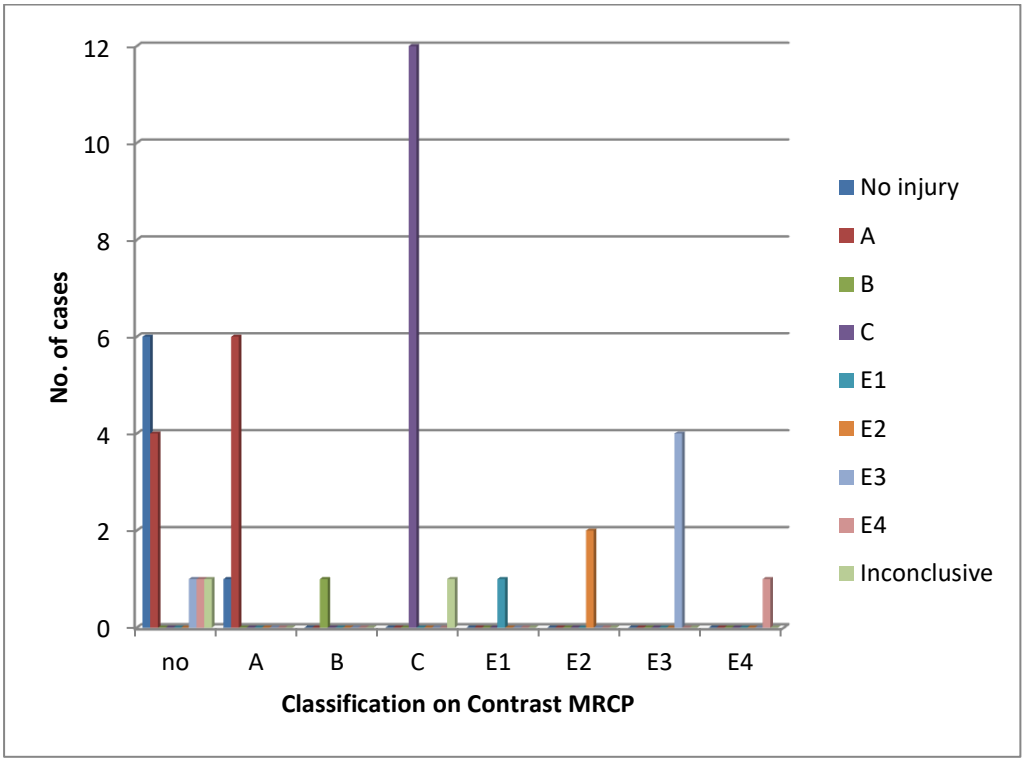
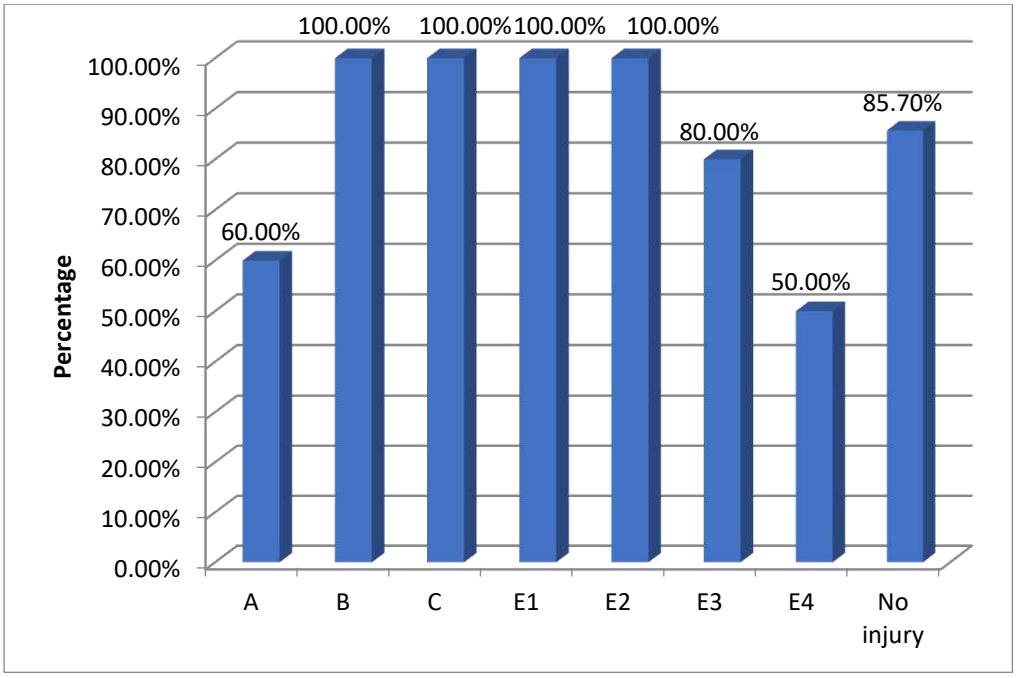


Table-38 Concordance between contrast MRCP and Surgery/ERCP in detecting bile duct injuries (2 patients were excluded as they had inconclusive results on ERCP)

	Strasberg classification on basis of Surgical/ ERCP findings	Classification on Contrast MRCP	
	No. of cases	No. of cases	CONOCORDANCE
A	10	6	60.0%
B	1	1	100.0%
C	12	12	100.0%
E1	1	1	100.0%
E2	2	2	100.0%
E3	5	4	80.0%
E4	2	1	50.0%
No injury	7	6	85.7%
TOTAL	40	33	82.5%

Figure 22- Concordance between contrast MRCP and Surgery/ERCP in detecting bile duct injuries (2 patients were excluded as they had inconclusive results on ERCP)



Combination of non-contrast and contrast-enhanced MRCP findings matched the surgical or ERCP findings in 36 cases. Amongst two patients with inconclusive ERCP results, combination of contrast and non-contrast MRCP identified a type C injury in one patient and a type B injury in the other. Six patients showed no bile duct injury on both combination of contrast and non-contrast and contrast MRCP as well as on surgery/ERCP, while one patient with reported type A injury (accessory duct leak in segment 8 of the liver) on using combined non contrast and contrast MRCP images, the surgical findings were negative for duct injury.

Among the 10 patients identified with type A injury by surgery/ERCP, combination of non-contrast and contrast enhanced MRCP detected the same injury in 7 patients, while the rest were found to have no injury. Both type B and E1 injuries were detected in one patient each by both surgery and combined approach. Combination of contrast and non contrast MRCP findings were consistent with surgical/ERCP findings for detecting type C injury in 12 patients, type E2 and E4 injuries in 2 patients each, and type E3 injury in 5 patients.(Refer Table 39 and 40, Figure 23 and 24)

Table 39- Comparison of various types of bile duct injuries detected on combined non contrast and contrast enhanced MRCP and Surgery/ERCP.

		Strasberg classification on basis of Surgical/ERCP findings									Total
		No injury	A	B	C	E1	E2	E3	E4	Inconclusive	
Classification of Injury (Combined non contrast and contrast MRCP)	No injury	6	3	0	0	0	0	0	0	0	9
	A	1	7	0	0	0	0	0	0	0	8
	B	0	0	1	0	0	0	0	0	1	2
	C	0	0	0	12	0	0	0	0	1	13
	E1	0	0	0	0	1	0	0	0	0	1
	E2	0	0	0	0	0	2	0	0	0	2
	E3	0	0	0	0	0	0	5	0	0	5
	E4	0	0	0	0	0	0	0	2	0	2
Total		7	10	1	12	1	2	5	2	2	42

Figure 23- Comparison of various types of bile duct injuries detected on combined non contrast and contrast enhanced MRCP and Surgery/ERCP.

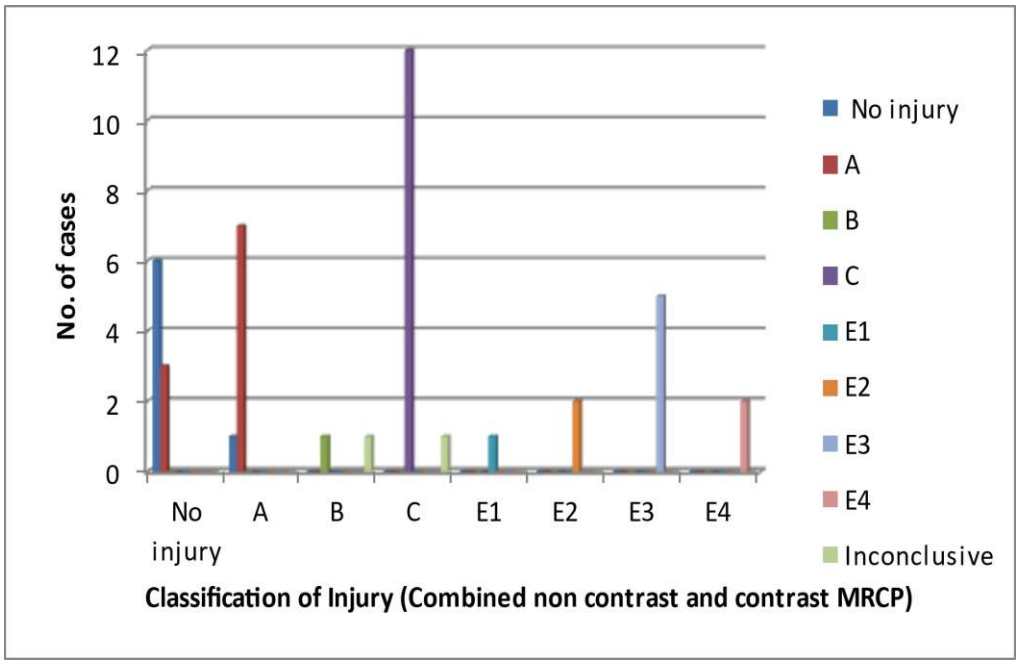


Table-40 Concordance between combined non contrast and contrast MRCP and Surgery/ERCP in detecting bile duct injuries (2 patients were excluded as they had inconclusive results on ERCP)

	Strasberg classification on basis of Surgical/ERCP findings	Classification of injury (Combined non contrast and contrast MRCP)	
	No. of cases	No. of cases	CONCORDANCE
A	10	7	70.0%
B	1	1	100.0%
C	12	12	100.0%
E1	1	1	100.0%
E2	2	2	100.0%
E3	5	5	100.0%
E4	2	2	100.0%
No Injury	7	6	85.7%
TOTAL	40	36	90.0%

Figure 24- Concordance between combined non contrast and contrast MRCP and Surgery/ERCP in detecting bile duct injuries (2 patients were excluded as they had inconclusive results on ERCP)

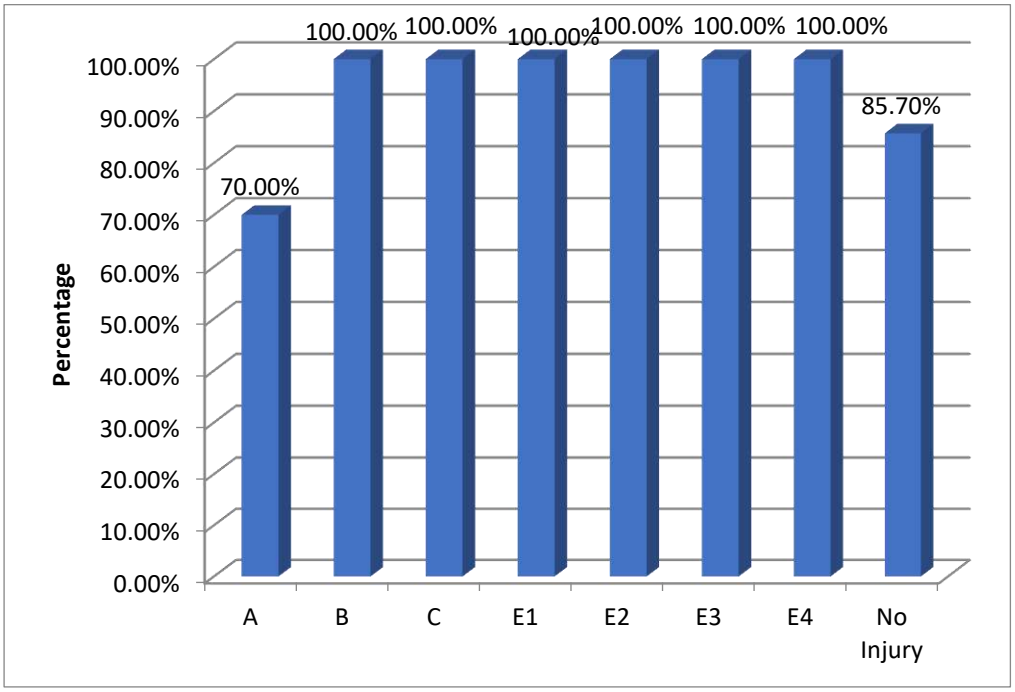


Table 41- Number of injuries that were present or absent on non-contrast MRCP as compared to Surgery/ERCP.

		Bile duct Injury on Surgey/ERCP		Total	Kappa value	p-value
		Absent	Present			
Bile duct Injury on Plain MRCP	Absent	5	13	18	0.198	0.122
	Present	2	20	22		
Total		7	33	40		

Table – 42 Sensitivity, specificity and accuracy of Non-contrast MRCP

Statistic	Value	95% CI
Sensitivity	60.61%	42.14% to 77.09%
Specificity	71.43%	29.04% to 96.33%
Accuracy (*)	62.50%	45.80% to 77.27%

Figure 25- Sensitivity, specificity and accuracy of Non-contrast MRCP

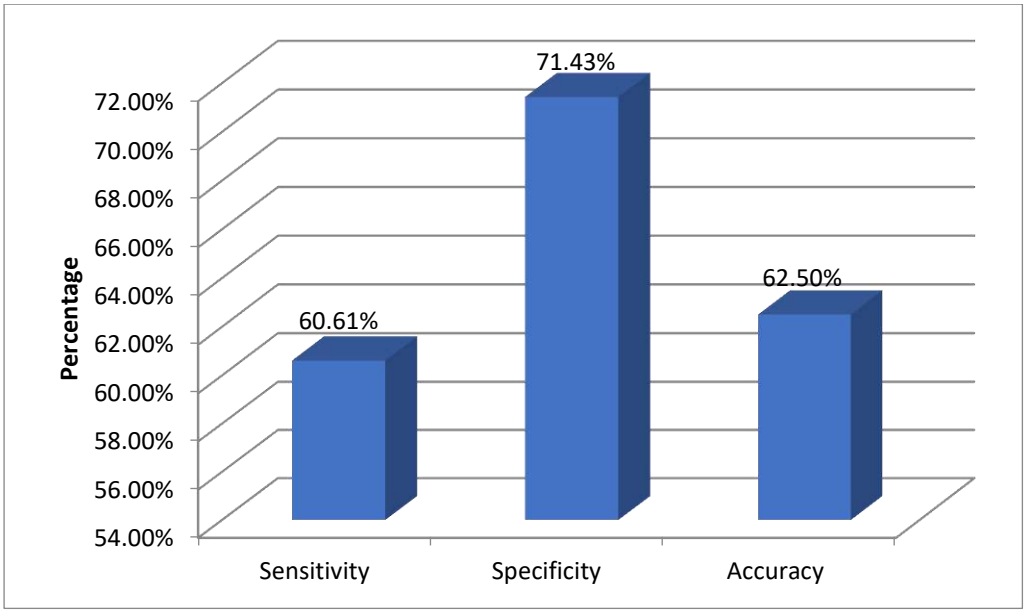


Table-43 Number of bile duct injuries present or absent on Contrast MRCP as compared to Surgery/ERCP.

		Bile duct Injury on Surgery/ERCP		Total	**Kappa value**	**p-value**
		Absent	Present			
Bile duct injury on Contrast MRCP	Absent	6	6	12	0.527	0.001
	Present	1	27	28		
Total		7	33	40		

Table -44 Sensitivity, specificity and accuracy of Contrast MRCP

Statistic	Value	95% CI
Sensitivity	81.82%	64.54% to 93.02%
Specificity	85.71%	42.13% to 99.64%
Accuracy (*)	82.50%	67.22% to 92.66%

Figure 26- Sensitivity, specificity and accuracy of Contrast MRCP

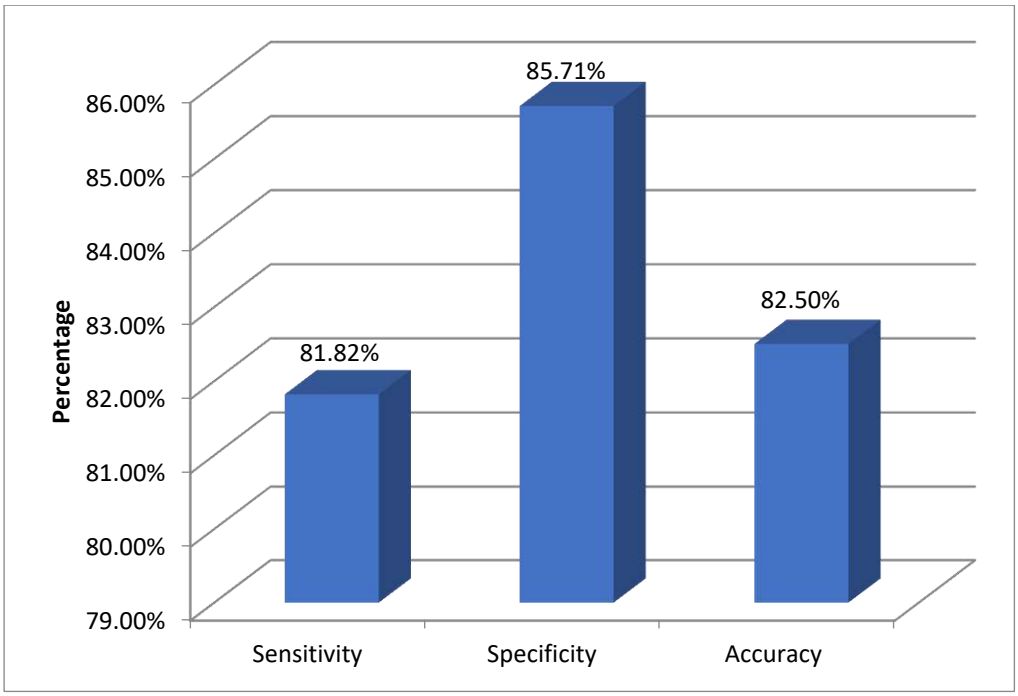


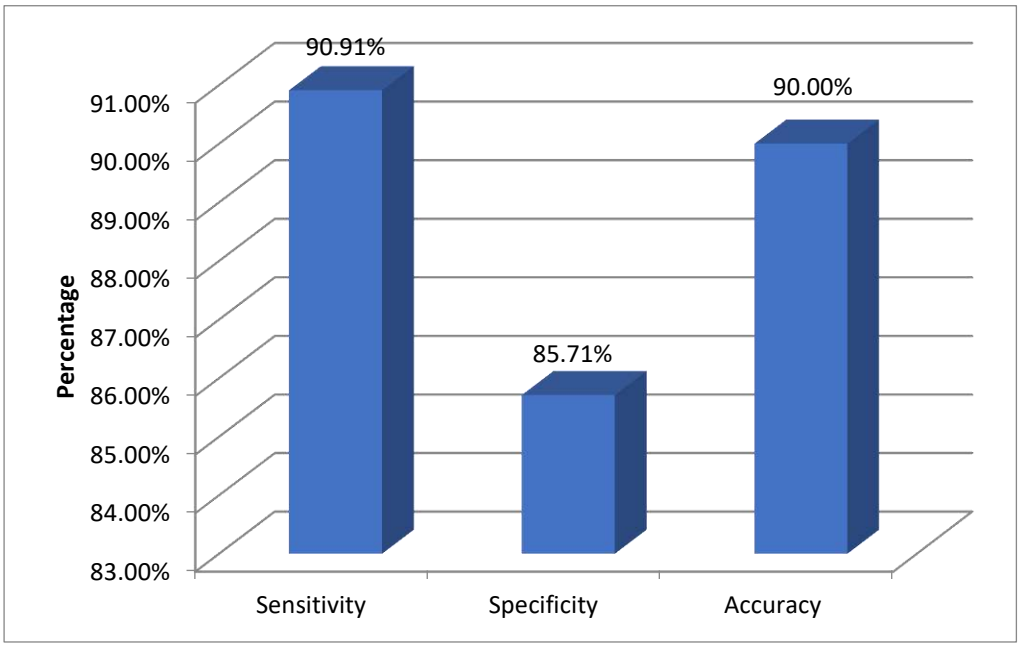
Table-45 Number of injuries present or absent on combined non-contrast and Contrast MRCP as compared to Surgery/ERCP.

		Bile duct Injury on Surgery/ERCP		Total	**Kappa value**	**p-value**
		Absent	Present			
Bile duct injury on Plain and Contrast	Absent	6	3	9	0.689	0.001
	Present	1	30	31		
Total		7	33	40		

Table-46 Sensitivity, specificity and accuracy of combined non-enhanced and contrast MRCP

Statistic	Value	95% CI
Sensitivity	90.91%	75.67% to 98.08%
Specificity	85.71%	42.13% to 99.64%
Accuracy (*)	90.00%	76.34% to 97.21%

Figure 27- Sensitivity, specificity and accuracy of combined non-enhanced and contrast MRCP



DISCUSSION

Bile duct injuries can occur due to iatrogenic and non-iatrogenic causes though majority of the bile duct injuries occur during biliary tract surgery especially laparoscopic cholecystectomy. Despite laparoscopic cholecystectomy being recognized as a safe and efficient method for removing a diseased gallbladder, it seems to be linked with an increased occurrence of bile duct injuries.[58]

In current study, 28 out of 42 patients who were suspected to have bile duct injuries had undergone laparoscopic cholecystectomy.

The prognosis for patients with bile tract injuries depends on factors such as the type, location, and severity of the injury, as well as the timing of diagnosis and the adequacy of initial treatment.[59–62] Early identification and prompt treatment of bile duct injuries are crucial, as immediate repair typically leads to the most favorable long-term outcomes. However, delayed recognition of biliary tract injuries continues to be a challenge. To mitigate this, employing routine drainage of the gallbladder bed postoperatively can aid in early detection of bile leakage, alongside the use of non-invasive techniques for swift diagnosis.

Amongst the current techniques to evaluate the biliary tree for suspected bile duct injuries, Ultrasonography and CT are the first-line diagnostic tools. Other techniques include MRCP, percutaneous transhepatic cholangiography and ERCP.[1,20] Sonographic and CT results may reveal various findings such as absence of collection, a distinct collection near the gall bladder or perihepatic area, a complicated or sizable perihepatic and subhepatic collection, and collections in other areas of the abdomen. However, their accuracy tends to be low, particularly when performed shortly after surgery. Both methods struggle to distinguish between postoperative hematoma, seroma, or bile leakage.[63] MRCP provides comprehensive and precise visualization of the biliary tree and collections, making it an effective diagnostic tool for identifying postoperative strictures and stones within the biliary tree.[64]

ERCP is useful to document the bile leak and is an excellent option for diagnostic and therapeutic management of bile duct injuries after laparoscopy. However, the invasive nature of this procedure can be potentially associated with major complications limiting its usage for sole diagnostic purposes.[65–68] Unfortunately, ERCP has a relatively poor sensitivity for diagnosis of injury to sectoral ducts of biliary tree.[19,20]

Currently, there are two hepatobiliary MR contrast media available for evaluation of biliary system. Gadolinium-ethoxybenzyl-diethylenetriamine pentaacetic acid (Gd-EOB-DTPA) also known as Primovist or Eovist and gadobenate dimeglumine (Gd-BOPTA) with a trade name of Multihance.

The delay time for hepatobiliary phase imaging is shorter with Gd-EOB-DTPA compared to Gd-BOPTA, owing to Gd-EOB-DTPA's higher biliary excretion rate of 50% versus Gd-BOPTA's 5%. This leads to a decreased total acquisition time for the study. Therefore, due to its comparable safety profile and faster imaging capabilities, Gd-EOB-DTPA is favored as the contrast agent for detecting biliary leaks. However, Gd-BOPTA provides superior enhancement of liver vessels and performs better in dynamic phase imaging.[69–72] In current study, GD-BOPTA was used for contrast enhanced MRCP due to availability of the contrast in our set up. GD-BOPTA is primarily eliminated via the renal route, hence the patients with compromised renal function may experience delayed clearance and increased risk of adverse events.[73]

Variations found in the hepatic ducts and cystic duct are among the primary factors leading to bile duct injuries.[19,74–76] These variant duct configurations might result in the misidentification of the cystic duct, accidental transection of the bile duct, or thermal harm that may go unnoticed during the operation.[23,77] In our study, 13(30.9%) patients were reported to have variant anatomy and 12(28.5%) patients of these suffered an iatrogenic injury. The most common variant anatomy was of right posterior duct draining into Common hepatic duct and was observed in 5 patients.

Our observations regarding variant biliary anatomy were in alignment with the study conducted by Yun Ho Chung et al[78] (2012) who performed a retrospective analysis of preoperative MRCP in patients who underwent laparoscopic cholecystectomy. They observed that ectopic drainage of right sectoral duct into common hepatic duct or cystic duct had high degree of risk of bile duct injury during surgery. They also summarized that anatomic variations are as important from a clinical view point.

Our findings are in parallel with Eikermann et al[79] (2012) who had performed a systematic research of the literature regarding prevention and diagnosis of bile duct injuries and reached a consensus that variant biliary anatomy is a strong risk factor for bile duct injuries.

In current study, our main aim was to evaluate the utility of MRCP in evaluation of bile duct injuries and evaluate the added advantage of using hepatobiliary contrast. Many studies have been done before to evaluate the use of non contrast MRCP in bile duct injuries whereas only few studies exist which have used combination of both non contrast and contrast enhanced MRCP.

In our study, non-contrast MRCP was able to detect and locate bile duct injury accurately in 62.5% of patients with a sensitivity of 60.6% and specificity of 71.4%. As compared to surgery/ERCP in which bile duct injuries were present in 33 out of 40 patients , non-contrast MRCP was able to accurately detect bile duct injuries in 20 patients. Non-contrast MRCP ruled out injury in 5 patients whereas 2 patients were false positive. Both false positive cases were of biliary stricture i.e 1 case involving the right anterior duct and other case involving right posterior duct. 2 results were rendered inconclusive on ERCP in which non contrast MRCP reported stricture involving right anterior duct in one case and no injury in another case.

Our findings are in concordance with the study conducted by Mecit et al[54] (2013) and Salvolini et al[52](2011).

Mecit et al[54](2013) conducted a comparative study between non-contrast and contrast-enhanced MRCP and they were able to detect and localize bile duct injury on non-contrast MRCP with an accuracy of

55% and 57%, the sensitivity of 53.3% and 63.6% and specificity of 60% and 51.8% in traumatic and post-surgery groups respectively.

In study done by Salvolini et al[52] (2011), non-contrast MRCP was able to detect biliary complications in 64% of patients post-surgery with a certainty.

Our findings are discordant with the studies done by Khalid et al[20] (2000), Bujanda et al[46] (2003) and Ragozzino et al[21] (2004) . These studies had close to 100% sensitivity in detection of the bile duct injuries by MRCP The most likely reason for discordance is the smaller size of patient population in these earlier studies as compared to our study.

In our study, contrast enhanced MRCP was able to detect and locate bile duct injuries accurately in 82.5% of patients with a sensitivity of 81.8% and specificity of 85.7%.In contrast to non-contrast MRCP, contrast enhanced MRCP enabled the identification of ongoing bile leakage through direct observation of the contrast agent seeping into the fluid collection. Moreover, it provided details regarding the precise anatomical site and nature of the bile duct injury. As compared to surgery/ERCP, contrast MRCP was able to detect and locate bile duct injuries accurately in 27 patients. Contrast enhanced MRCP accurately ruled out injury in 6 patients and 1 patient was false positive in which leak from accessory duct draining segment VIII was seen and no injury was found on surgery. However, possibility of self-limiting leak was not ruled out in this particular patient. In 2 patients in which bile duct stricture was reported on non-contrast MRCP, adequate opacification was achieved on contrast MRCP, thus ruling out injury in those two patients. Non-opacification of the biliary system was seen in 4 patients in whom bile duct injuries were reported on non-contrast MRCP. 3 patients later proved to have bile duct injuries on ERCP/surgery and 1 ERCP examination was rendered inconclusive in which bile duct stricture of the right anterior duct was reported on non-contrast MRCP and adequate opacification of the biliary system was not achieved via contrast MRCP. Contrast enhanced MRCP reported 1 Type C injury involving the segment 5 draining duct, however, ERCP was rendered

inconclusive in this case and non-contrast MRCP was not able to detect and localize the injury . There was a biloma in this particular case with contrast leak in the biloma which was suggestive of a bile duct injury.

Our findings are in agreement to study done by Vitellas K et al[45] (2002) who used mangafodipir trisodium as a contrast agent. Only contrast enhanced MRCP was performed in their study and no non-contrast MRCP images were acquired. Contrast-enhanced MRCP identified bile duct leaks in six patients and ruled out bile duct leaks in five patients, with one false-negative and one false-positive finding for bile duct leak (sensitivity, 86%; specificity, 83%).

In current study, combined non contrast and contrast MRCP was able to detect and locate bile duct injuries accurately in 90% of patients with a sensitivity of 90.9% and specificity of 85.7%. In addition to detecting and localizing additional bile duct injuries which were not found on non-contrast MRCP, contrast enhanced increased the confidence by showing active leaks in transection injuries and non-opacification of narrowed segment in biliary stricture in whom bile duct injuries were already reported via non-contrast MRCP. However, as mentioned earlier, non-opacification of biliary system was seen in 4 patients in whom bile duct injuries were reported on non-contrast MRCP. Therefore, combined non-contrast and contrast MRCP had greater accuracy and sensitivity in detecting and localizing bile duct injuries.

Our study findings are in alignment with study done by Mecit K et al[54] (2013), they found that combined non-contrast and contrast MRCP had an accuracy of 75% and 91.4% and sensitivity of 80% and 76% in detecting and localizing bile duct injuries in trauma and post-surgery groups respectively.

Our findings are also in concordance with Aduna M et al[50] (2005) who found that combined contrast and non-contrast MRCP had accuracy of 97.1% with a sensitivity of 95.1% in detecting and localizing bile duct injury. However, specificity of both the above mentioned studies was 100% as compared to our specificity.

Our analysis is also in parallel with Salvolini et al[52] (2011) who found that combined contrast and non-contrast MRCP had sensitivity of 100% in detecting and localizing bile duct injuries and Castellanos et al[53] (2012) who conducted a prospective study involving twenty-three patients exhibiting symptoms suggestive of bile leaks and found that combined non-contrast and contrast MRCP had a diagnostic accuracy of 100% in detecting bile leaks. However, these studies had a specificity of 100% as compared to our specificity of 85.7%. In terms of specificity, reasons can be attributed to low sample size in our study who did not have any bile duct injury and out of them, one patient had accessory duct leak which was not found on surgery so the patient was labelled as false positive , however, possibility of self-limiting leak was not ruled out.

Strasberg classification was originally described for post-cholecystectomy bile duct injuries and is the most common and widely used classification system for bile duct injuries. In current study, we used Strasberg classification to classify both iatrogenic as well as non-iatrogenic bile duct injuries.

In current study, Type C(12 cases) injury was the most common form of bile duct injury which was found on surgery/ERCP followed by Type A(10 cases) and Type E3(5 cases). Type E2 and E4 had similar incidence of 2 cases each whereas only 1 case each of type E1 and Type B injury was found. 2 cases were rendered inconclusive on ERCP as ERCP was not able to evaluate the proximal biliary system in which proximal biliary injuries were reported by MRCP i.e Type B injury involving right anterior duct and Type C injury involving duct draining segment V of liver. Our combined non contrast and contrast MRCP analysis had a concordance of 90% with surgery/ERCP findings in terms of classifying bile duct injuries according to Strasberg classification.

M Leguia et al[57] (2024) did a retrospective study on 20 patients and found on surgery/ERCP that type E2 and type E4 was the most common form of bile duct injury and were 5 cases each followed by Type A,D and E1 injury which were 2 cases each. Type C and E3 injury

were present in 1 case each. Their study had a concordance of 70% in terms of classifying injuries on both MRCP and surgery/ERCP.

H Q Vu et al[80] (2023) found that out of 28 patients, Type A (13 cases) injury was the most common bile duct injury in their study followed by Type E3(5 cases), Type E2(4 cases).

Abdelgawad M et al[81] (2023) did a prospective study and found that out of 37 patients, most common type of injury was Type E2 found in 29.7% patients and least common were Type B and Type E4 injuries in 2.7% patients each.

Although the majority of studies[82] done before concluded that Type A is the most prevalent form of bile duct injury, in our study Type C followed by Type A were the most common forms of bile duct injury. The cause can be linked to varying patient demographics, incidence and pattern of biliary variations and possibly related to surgical expertise across various studies. Also, previous studies majorly included post cholecystectomy bile duct injuries whereas in our study, both iatrogenic and non-iatrogenic causes of bile duct injuries have been taken into account. In non-iatrogenic injuries, 4 cases were of Type C bile duct injury and 1 case was of Type E1 bile duct injury.

In our study, based on MRCP findings, 22 patients underwent surgery and 20 patients underwent ERCP procedure. In 6 patients in whom no bile duct injury was found on MRCP as well as surgery/ERCP but suspicion of injury was kept due to deranged LFTs and consistent clinical symptoms, 2 underwent diagnostic ERCP and 4 underwent diagnostic laparoscopy. Diagnostic and therapeutic ERCP in form of CBD stenting and sphincterotomy was done in 7 patients in whom MRCP reported Type A injury, 1 patient of Type E2 and Type E3 injury each. 1 patient was reported to have biliary stricture involving the right anterior duct and 1 patient had type C injury involving the segment 5 duct and diagnostic ERCP was inconclusive in both of the cases, however, CBD stenting and sphincterotomy was done in both of the patients. CBD stenting and sphincterotomy was also done in 1 patient of type C injury involving right posterior duct who refused to undergo

surgery. LHD stenting and sphincterotomy was done in patients who suffered from Type C injury of left ductal system. Rest of the patients who suffered from Type C injury of bile duct underwent hepaticojejunostomy.

Table 47- Various interventions patients underwent according to Strasberg classification on combined non contrast and contrast MRCP

		Surgery/ ERCP					Total
		CBD Stenting and sphincterotomy	Diagnostic ERCP	Diagnostic Laparoscopy	Hepaticojejunostomy	LHD STENTING AND SPHINCTEROTOMY	
Strasberg CLASSIFICATION OF INJURY (Combined non contrast and contrast MRCP)	No injury	3	2	4	0	0	9
	A	7	0	1	0	0	8
	B	1	0	0	1	0	2
	C	2	0	0	8	3	13
	E1	0	0	0	1	0	1
	E2	1	0	0	1	0	2
	E3	1	0	0	4	0	5
	E4	0	0	0	2	0	2
Total		15	2	5	17	3	42

In study done by Aduna M et al[50] (2005), cystic duct leaks were primarily addressed through direct stitching, while common hepatic duct injuries typically required biliary enteric anastomosis to restore bile flow. For small leaks, the usual approach involved drainage using percutaneous, endoscopic, or surgical techniques.

Minor leaks are managed by performing a sphincterotomy and inserting a stent to redirect bile flow away from the affected area, allowing it to heal temporarily.[1,83,84] Surgery, endoscopic papillotomy, or placement of an internal biliary stent may be necessary to address bile leaks or fistulas. Excision and injuries involving strictures generally require surgery.[1,85]

SUMMARY AND CONCLUSION

Summary:

- Our study included 42 patients with maximum number of patients(13 out of 42) between 41-50 years of age.
- The most common method of bile duct injury was iatrogenic. Out of 42 patients, 37 patients had undergone cholecystectomy and 5 patients suffered traumatic injury.
- The most common complain of the patients was generalized pain abdomen in 31(73.8%) patients.
- Conventional biliary anatomy was observed in 29 subjects (69%) while variant biliary anatomy was observed in 13 (31%).Right posterior duct draining into common hepatic duct was the most common variant observed.
- Strasberg Type C injury was the most common type of injury observed in our analysis.
- The sensitivity, specificity and diagnostic accuracy of non-contrast MRCP for detection and localization of bile duct injuries was 60.6%, 71.4% and 62.5% respectively.
- The sensitivity, specificity and diagnostic accuracy of contrast MRCP for detection and localization of bile duct injuries was 81.8%,85.7% and 82.5% respectively.
- On combination of non-contrast and contrast enhanced MRCP, the sensitivity and diagnostic accuracy of got further improved. The sensitivity was 90.9% and accuracy was 90%.

Conclusion:

Our study concluded that MRCP is an excellent tool for assessment of the biliary tree both pre-operatively and post-operatively, in assessment of biliary tree variations, involvement of the bile ducts by disease and assessment of the injuries to both intra-hepatic and extrahepatic biliary system. MRCP serves as a roadmap for planning therapeutic interventions in various subsets of patients. Integrity of the bile ducts in particular the major central ducts, hepatic hilum can be assessed to a high accuracy using contrast-enhanced MRCP. Contrast

enhanced MRCP can precisely localise the site of leak in a significant number of patients with suspected bile duct injuries and can act as a guide for a very precise and targeted treatment in these patients. A combination of non-contrast MRCP and contrast enhanced MRCP can predict the kind of biliary injury in most of the cases as concluded by our study as well as the prior literature.

Limitation

Although data from our study is encouraging, the major limitation of our study was that it was a single centre study and the sample size of the study was relatively small. Study with a larger sample size can further validate the accuracy of this imaging procedure.

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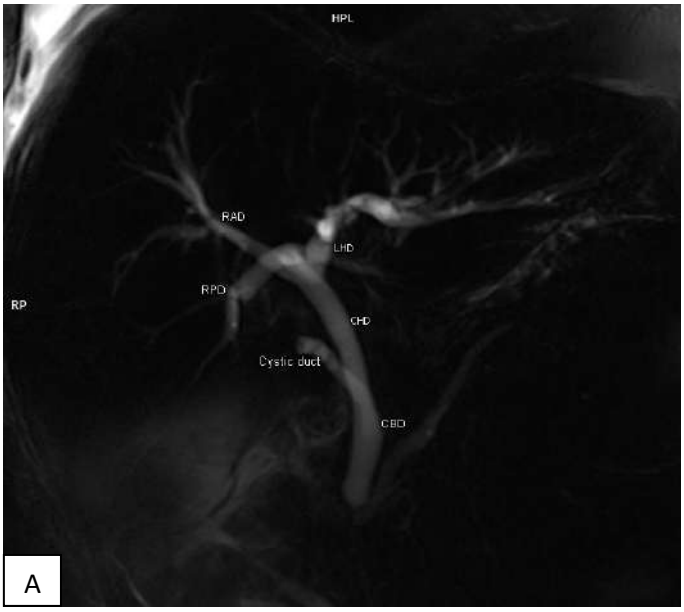
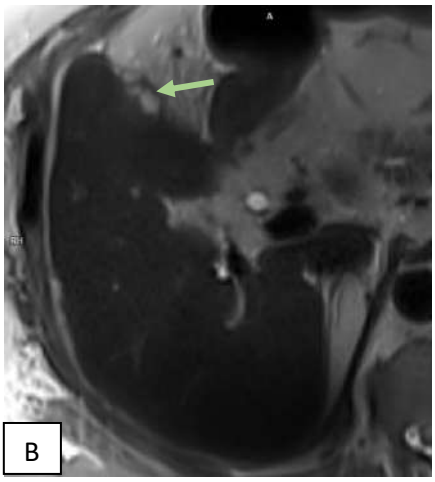
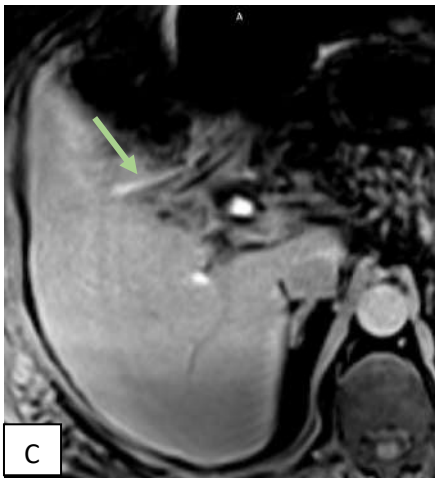
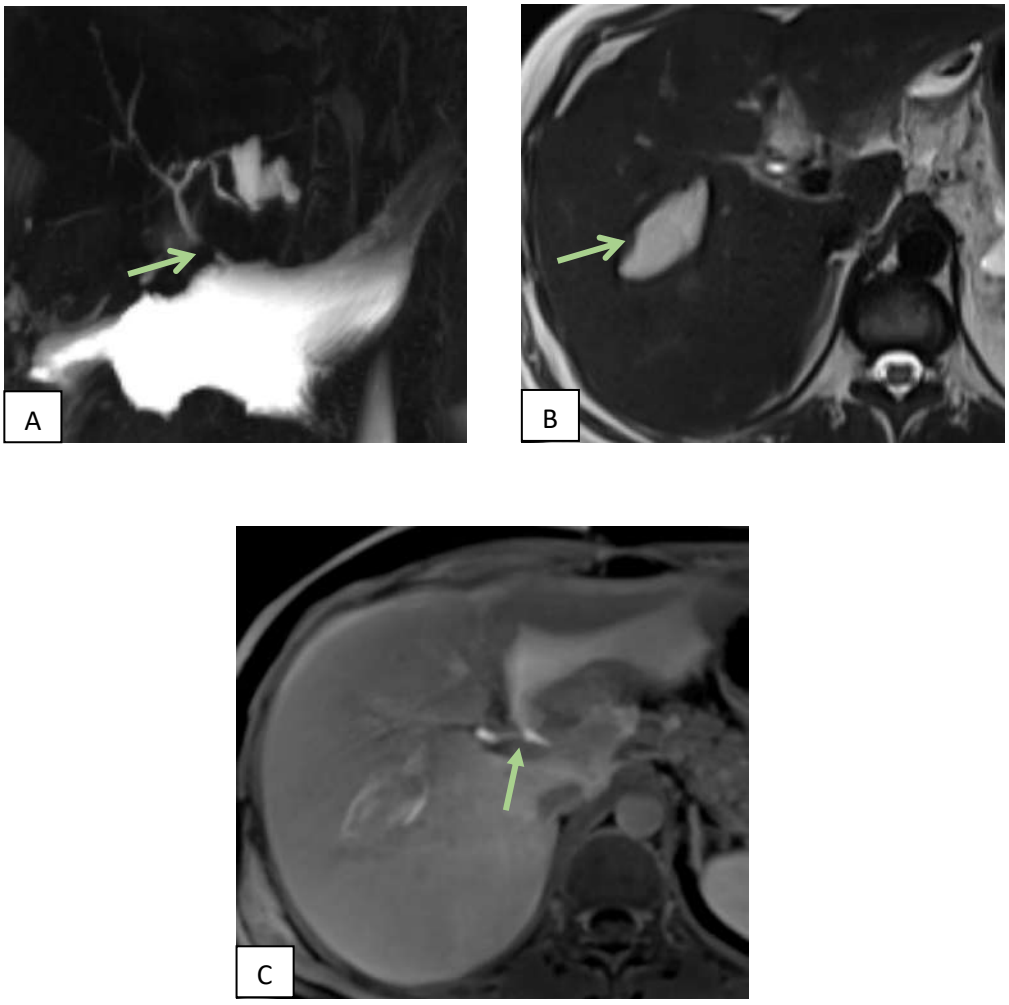


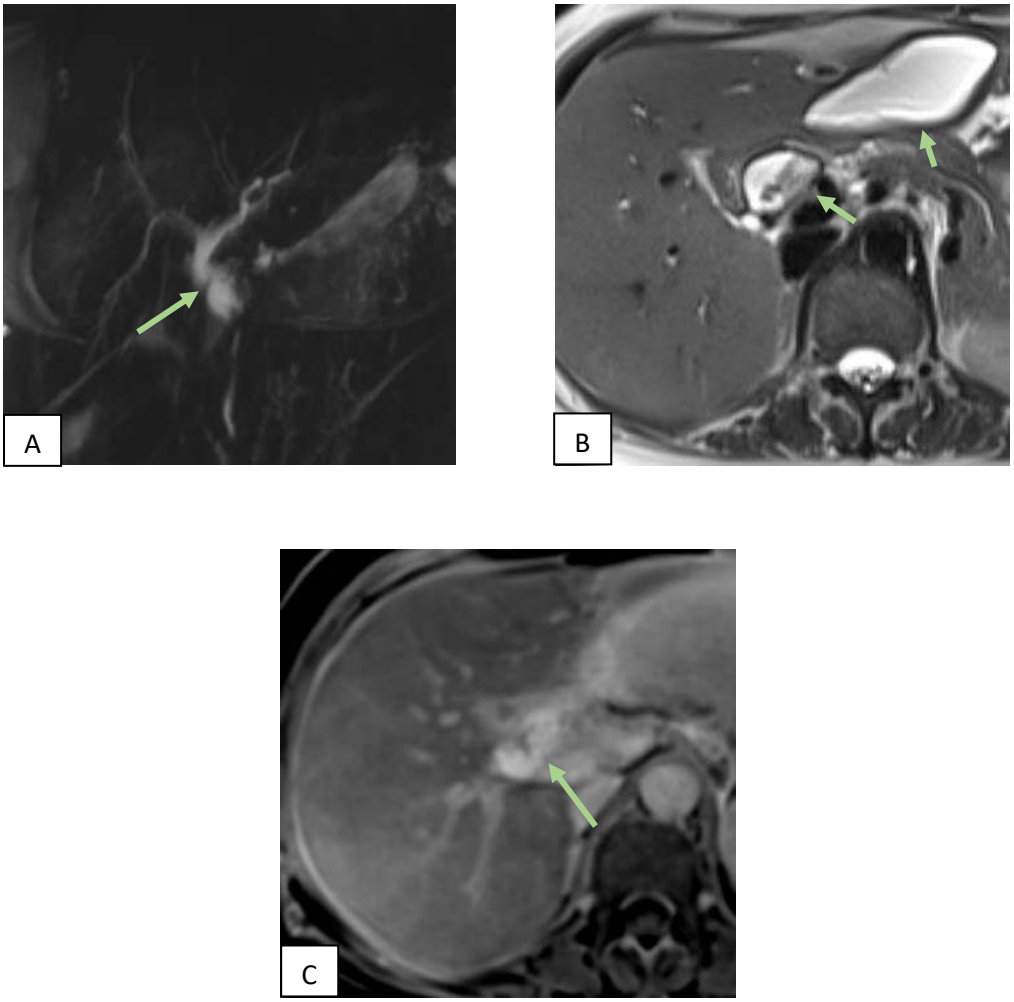




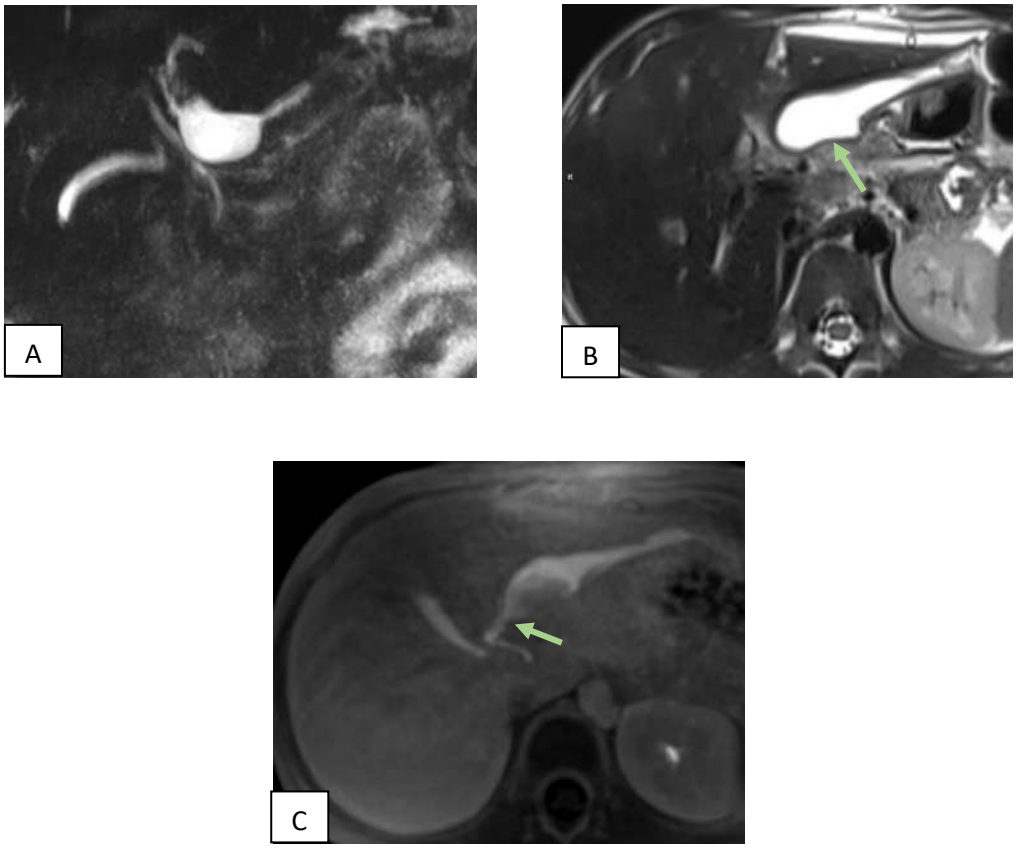
Picture 4: A 65 year old male patient with pain abdomen and generalized weakness post cholecystectomy. (A) MIP 3D MRCP image shows normal CBD,CHD and primary confluence with low anteromedial insertion of cystic duct (B) Axial T2WI image shows T2 hyperintense small biloma in gall bladder fossa (C) T1WI post contrast 2 hour delayed image shows streak of contrast along the drain likely originating from duct draining segment 5 s/o Strasberg Type C injury. ERCP was done in this case and was inconclusive.



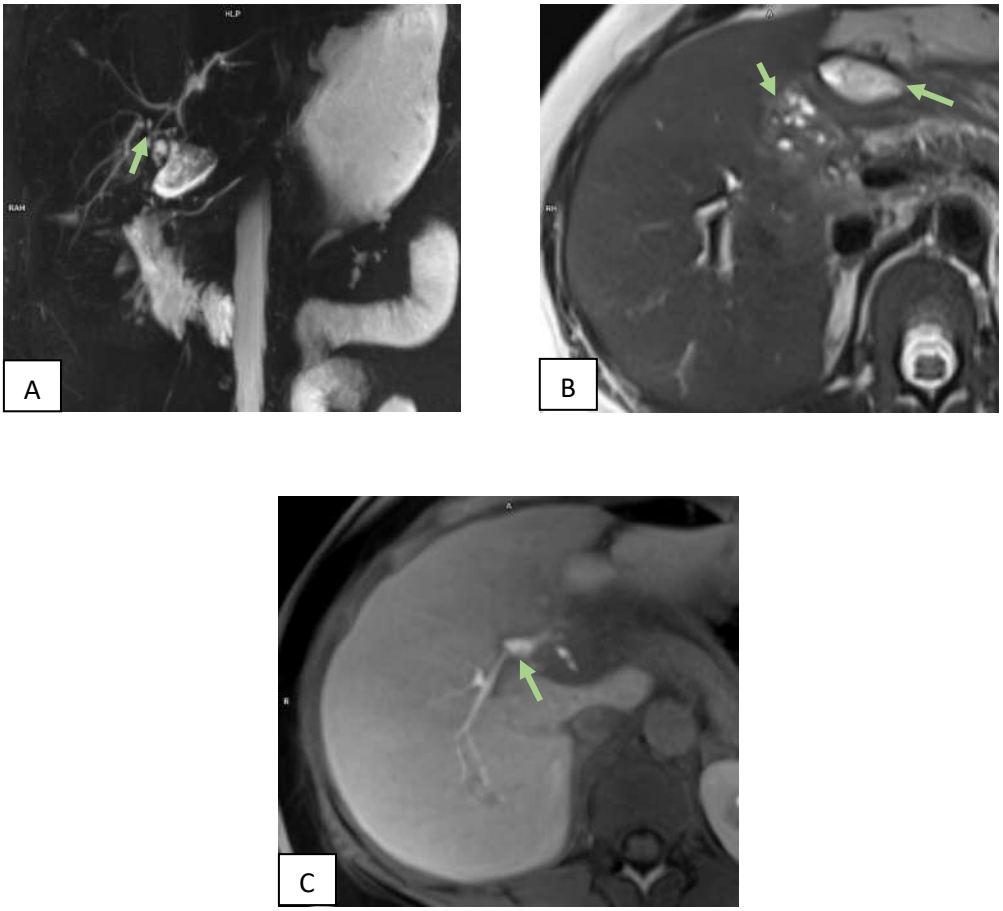
Picture 5: A 27 year old male patient with pain abdomen post trauma (A) MIP 3D MRCP image shows non visualization of segment of common bile duct with ill defined collection. (B) Axial T2WI shows biloma formation in laceration in Segment 6. (C) T1 post contrast 2 hour delayed image shows extravasation of contrast from common bile duct into the perihepatic space s/o Strasberg Type E1 injury. Surgical findings confirmed the same.



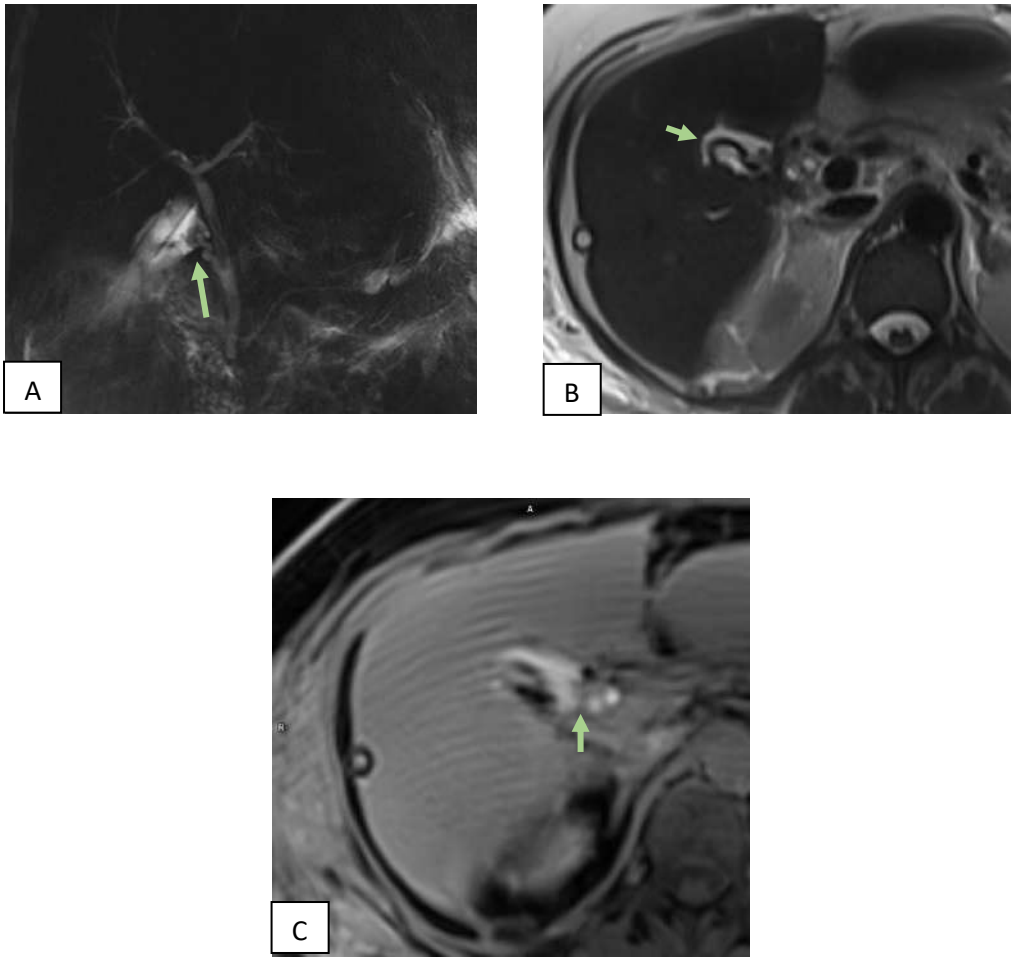
Picture 6: A 51 year old female patient with pain abdomen and fever post cholecystectomy (A) MIP 3D MRCP image shows non visualization of common hepatic duct just at the primary confluence with intact primary confluence (B) Axial T2WI shows biloma in gall bladder fossa and subhepatic space (C) T1 post contrast 2 hour delayed image shows extravasation of contrast from common hepatic duct into the collection s/o Strasberg type E3 injury. Surgical findings confirmed the same.



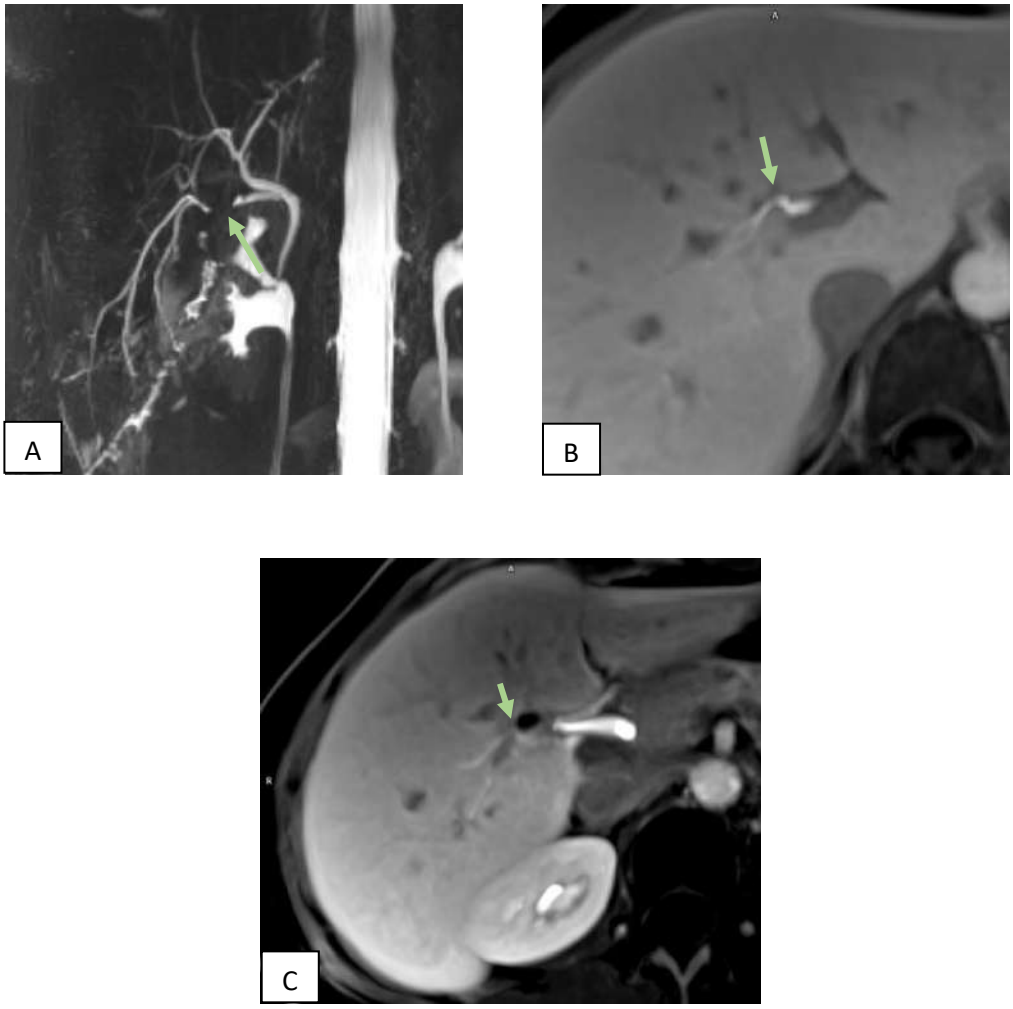
Picture 7: A 3 year old male patient presented with pain abdomen post trauma (A) MIP 3D MRCP image shows normal gall bladder, CBD and CHD and a collection adjacent to it (B) Axial T2WI shows biloma in left subhepatic space (C) T1 post contrast 1 hour delayed image shows non visualization of proximal left hepatic duct just after formation of primary confluence with extravasation of contrast into subhepatic space s/o Strasberg type C injury. ERCP findings confirmed the same.



Picture 8: A 55 year old female patient with fever and bilious discharge from surgical drain post cholecystectomy (A) MIP 3D MRCP image shows non visualization of proximal right posterior duct with intact primary confluence. (B) Axial T2WI image shows small T2 hyperintense collections in subhepatic space. (C) T1 post contrast 2 hour delayed images show extravasation of biliary contrast from right posterior duct into the collection s/o Strasberg Type C injury. Surgical findings confirmed the same.



Picture 9: A 62 year old female patient with pain abdomen and fever post cholecystectomy (A) MIP 3D MRCP image shows intact primary confluence with collection adjacent cystic duct stump (B) Axial T2WI shows biloma in gall bladder fossa with surgical drain in situ (C) T1 post contrast delayed 1 hour image shows extravasation of contrast into the biloma adjacent cystic duct s/o Strasberg Type A injury. ERCP findings confirmed the same.



Picture 10: A 26 year old female patient with bilious discharge in surgical drain post cholecystectomy (A) MIP 3D MRCP image shows non visualization of part of duct draining segment 5 (B) T1 post contrast 1 hour delayed image shows the normal opacification of primary confluence (C) T1 post contrast 1 hour delayed image shows cut off of duct draining segment 5 adjacent to surgical drain with extravasation of contrast into and adjacent the surgical drain likely from duct draining segment 5 s/o Strasberg type C injury. Surgical findings confirmed the same.

Picture 11: A 74 year old male patient presented with pain abdomen post cholecystectomy (A) Axial T2WI shows accessory duct arising from segment 8 of liver not joining the biliary system. No obvious collection is seen. (B) T1 post contrast 2 hour delayed image shows the normal opacification of primary confluence (C) T1 post contrast 2 hour delayed image shows abrupt cut off of duct draining segment 8 with leaked out contrast in segment 8 and perihepatic space s/o Strasberg type A injury. However no biliary leak was identified on surgery.

Key to Masterchart

Sex

1- Male
2- Female

Mechanism of injury

1- Iatrogenic
2- Non-Iatrogenic

Variant Anatomy

1- No
2- Yes

Biliary stricture(on non-contrast MRCP)

1- Absent
2- Present

Cystic duct leak(on non-contrast MRCP)

1- Absent
2- Present

Bile duct leak(on non-contrast MRCP)

1- Absent
1- Present

Dilated IHBR

1- No
2- Yes

Free Fluid

1- No
1- Yes

Contrast Used

1- No
2- Yes

If yes, Extravasation present

1- No
2- Yes

Extravasation from Cystic Duct

1- No
2- Yes

Extravasation from Bile duct

1- No
2- Yes

Transection of hepatic duct(on non-contrast and contrast MRCP)

1- Absent
2- Present

Transection of Hepatic duct(on non-contrast MRCP)

1- Absent
2- Present

Dilated CBD

1- No
2- Yes

Biloma formation

1- No
2- Yes

S.No.	MRD	INITIALS	AGE	SEX	CHIEF COMPLAINTS	MECHANISM OF INJURY	If Iatrogenic, Specify	HAEMOGLOBIN	TLC	PLATELETS	T. BILIRUBIN	D. BILIRUBIN	SGOT	SGPT	ALP	ALBUMIN
1	1352571	NT	26	2	Bilious discharge from surgical drain,fever and pain abdomen	1	Lap cholecystectomy	10.2	18.8	178	0.56	0.14	46	60	227	3.6
2	1362823	S	52	2	Bilious discharge from surgical drain,fever and pain abdomen	1	Lap cholecystectomy	10.5	37.4	546	0.82	0.32	30	20	167	2.4
3	1350133	PD	58	2	Bilious discharge from surgical drain,fever	1	Lap cholecystectomy	9.4	32.3	531	0.81	0.16	38	36	182	3.6
4	1370718	SW	56	2	Bilious discharge from surgical drain,fever	1	Lap cholecystectomy	11.1	5.8	169	0.85	0.39	51	45	164	3.4
5	1445530	SK	39	1	Fever, pain abdomen	1	Lap cholecystectomy	13.8	14.9	354	1.57	0.95	21	48	240	3.3
6	1461760	ZK	62	1	Bilious discharge from surgical drain	1	Lap cholecystectomy	10.5	11.1	591	0.53	0.2	53	56	341	2.6
7	1400796	MK	51	2	Fever, pain abdomen	1	Open cholecystectomy	9.2	25.8	572	0.72	0.54	22	21	256	2.1
8	1467399	D	55	2	Bilious discharge from surgical drain,fever	1	Lap cholecystectomy	10.6	12.5	150	0.91	0.23	48	46	242	3.3
9	1465442	HS	61	1	Generalized weakness, Fever	1	Open cholecystectomy	10.8	11.2	464	1.1	0.69	115	99	268	4.1
10	1482834	IK	74	1	Pain abdomen	1	Lap cholecystectomy	7.3	8	251	0.88	0.21	47	47	132	4.1
11	1512467	MS	70	1	Generalized weakness, Fever	1	Open cholecystectomy	13.6	12	223	1.09	0.37	48	42	52	3.08
12	1515653	J	47	1	Bilious discharge from surgical drain	1	Lap cholecystectomy	9	5.9	170	0.91	0.31	20	11	236	2.5
13	1508360	JS	16	1	Road side accident with pain abdomen	2	-	9.9	16.6	395	0.88	0.65	24	34	305	2.4
14	1510473	RK	34	2	Pain abdomen, Fever	1	Lap cholecystectomy	10.1	11.7	332	1.2	0.77	109	351	332	3.4
15	1522480	BK	62	1	Pain abdomen, Fever, Icterus	1	Lap cholecystectomy	11.1	11.2	226	2.5	2.2	48	38	142	1.9
16	1523125	VK	36	1	Pain,abdomen,Fever,Bilious discharge from surgical drain	1	Open cholecystectomy	9.2	27.4	202	6.1	5.3	38	43	165	2.1
17	1504215	SK	39	2	Pain abdomen, Non healing surgical wound	1	Lap cholecystectomy	10.7	8.2	455	0.93	0.5	43	42	171	4.1
18	1559011	RK	49	2	pain abdomen	1	Lap cholecystectomy	11.9	12.2	276	1.29	0.34	91	97	183	3.8
19	1591354	BK	25	2	Bilious discharge from surgical drain,pain abdomen	1	Open cholecystectomy	8.5	17.5	489	1.95	1.37	40	38	133	3.6
20	1576253	PD	63	2	Pain abdomen	1	Lap cholecystectomy	11.1	10.8	212	0.4	0.1	29	40	401	3.5
21	1558352	GK	31	2	Pain abdomen,Icterus,Bilious discharge from surgical drain	1	Open cholecystectomy	11	13.1	402	3.8	2.5	42	54	265	3
22	1618460	AR	56	1	pain abdomen, generalized weakness	1	Lap cholecystectomy	11.3	12.8	205	1.2	0.54	49	49	150	2.7

S.No.	MRD	INITIALS	CREATININE	UREA	ANY OTHER POSITIVE INVESTIGATION	VARIANT ANATOMY	IF PRESENT, SUBTYPE	BILIARY STRICTURES (on Non contrast MRCP)	IF PRESENT, SITE	CYTIC DUCT LEAK (on non-contrast MRCP)	BILE DUCT LEAK(on non contrast MRCP)	TRANSECTION OF HEPATIC DUCT(Non contrast MRCP)
1	1352571	NT	0.54	12	Fasting Blood glucose = 174	1	NA	1	NA	1	2	2
2	1362823	S	1.7	62	NA	1	NA	1	NA	1	1	1
3	1350133	PD	0.82	40	NA	1	NA	1	NA	1	1	1
4	1370718	SW	0.92	18	Random Blood Sugar = 309	1	NA	1	NA	1	1	1
5	1445530	SK	0.79	28	INR = 1.4	1	NA	1	NA	1	1	1
6	1461760	ZK	0.91	14	NA	2	Right Posterior Duct Draining into CHD	1	NA	1	2	2
7	1400796	MK	0.5	4	NA	1	NA	1	NA	1	2	2
8	1467399	D	0.45	15	NA	2	Right Posterior Duct Draining into CHD	1	NA	1	2	2
9	1465442	HS	0.46	11	NA	2	Accessory duct draining segment 5	1	NA	1	2	2
10	1482834	IK	1.24	29	NA	2	Accessory duct draining segment 8	1	NA	1	1	1
11	1512467	MS	0.66	27	NA	1	NA	1	NA	2	1	1
12	1515653	J	0.76	22	NA	1	NA	1	NA	1	1	1
13	1508360	JS	0.29	9	NA	1	NA	1	NA	1	1	1
14	1510473	RK	0.86	13	S.amylase =971,S. Lipase = 1325	2	Right Posterior Duct Draining into CHD	1	NA	1	1	1
15	1522480	BK	2.4	114	NA	1	NA	1	NA	1	1	1
16	1523125	VK	0.5	12	NA	1	NA	1	NA	1	2	2
17	1504215	SK	0.53	12	NA	1	NA	1	NA	1	1	1
18	1559011	RK	0.45	11	S.Amylase =374,S. Lipase = 525	1	NA	1	NA	1	1	1
19	1591354	BK	0.74	14	NA	1	NA	1	NA	1	2	2
20	1576253	PD	0.76	33	NA	2	Trifurcation	2	Right anterior duct	1	1	1
21	1558352	GK	0.61	7	NA	1	NA	1	NA	1	2	2
22	1618460	AR	0.6	11	NA	1	NA	1	NA	1	2	2

S.No.	MRD	INITIALS	If Transection present, Hepatic duct involved	DILATED IHBR	DILATED CBD	FREE FLUID	BILIOMA FORMATION	IF Present, SITE	LENGTH OF CBD INTACT(cm)	CONTRAST USED	If yes, Extravastion present	Extravasation from Cystic duct	Extravasation from Bile duct
1	1352571	NT	Segment 5 Duct	1	1	1	1	NA	3.7	2	2	1	2
2	1362823	S	NA	1	1	1	2	GB FOSSA	5.7	2	2	2	1
3	1350133	PD	NA	1	1	1	2	GB FOSSA	4.8	2	2	2	1
4	1370718	SW	NA	1	1	1	2	GB FOSSA AND PERIHEPATIC LOCATION	4.6	2	2	2	1
5	1445530	SK	NA	1	1	1	2	GB FOSSA	4.2	2	1	1	1
6	1461760	ZK	Right posterior duct	1	1	1	2	GB FOSSA AND PERIHEPATIC LOCATION	5.1	2	2	1	2
7	1400796	MK	CHD	1	1	1	2	GB FOSSA AND GASTROHEPATIC LIGAMENT	3.3	2	2	1	2
8	1467399	D	Right posterior duct	2	1	1	2	PERIHEPATIC LOCATION	4.8	2	2	1	2
9	1465442	HS	CHD and Primary confluence	1	1	1	2	GB FOSSA AND PERIHEPATIC LOCATION	4.6	2	1	1	1
10	1482834	IK	NA	1	1	1	1	NA	5.4	2	2	1	2
11	1512467	MS	NA	1	2	1	2	GB FOSSA ADJACENT TO CYSTIC DUCT	5.1	2	1	1	1
12	1515653	J	NA	1	1	1	2	GB FOSSA	4.8	2	2	2	1
13	1508360	JS	NA	1	1	1	2	Segment 4 and gb fossa	4.2	2	2	1	2
14	1510473	RK	NA	1	2	1	2	GB FOSSA	5.6	2	1	1	1
15	1522480	BK	NA	1	1	1	2	GB FOSSA AND PERIHEPATIC LOCATION	4.5	2	2	2	1
16	1523125	VK	Suprapancreatic CBD and CHD	1	1	1	2	SUBPHRENIC AND PERIHEPATIC LOCATION	1.2	2	1	1	1
17	1504215	SK	NA	1	1	1	2	GB FOSSA EXTENDING TO LUMBAR REGION	4.7	2	2	2	1
18	1559011	RK	NA	1	1	1	2	Segment 4B	4.9	2	2	1	2
19	1591354	BK	CHD and Primary confluence	1	1	1	2	GB FOSSA AND SUBHEPATIC LOCATION	4.1	2	2	1	2
20	1576253	PD	NA	2	1	1	1	NA	5.2	2	1	1	1
21	1558352	GK	Suprapancreatic CBD and CHD	1	1	1	2	GB FOSSA	3.7	2	2	1	2
22	1618460	AR	CHD	1	1	1	2	GB FOSSA	3.9	2	2	1	2

S.No.	MRD	INITIALS	TRANSECTION OF HEPATIC DUCT (non contrast and contrast MRCP)	Transection seen on non contrast and Contrast , Specify	Strasberg Classification on non-contrast MRCP	Strasberg Classification on Contrast MRCP	Strasberg classification on combined non contrast and contrast MRCP	comments
1	1352571	NT	2	Segment 5 Duct	C	C	C	Extravasation from Segment 5 duct into surgical drain
2	1362823	S	1	NA	-	A	A	Extrvasation from cystic duct stump into the collection
3	1350133	PD	1	NA	-	A	A	Extravasation from cystic duct stump into the collection
4	1370718	SW	1	NA	-	A	A	Extravasation from cystic duct stump into the collection
5	1445530	SK	1	NA	-	-	-	No extravasation
6	1461760	ZK	2	Right posterior duct	C	C	C	Extravasation from Right posterior duct close to its insertion into CHD into the collection
7	1400796	MK	2	CHD	E3	E3	E3	Extravasation from CHD into the collection
8	1467399	D	2	Right posterior duct	C	C	C	Extravasation from Right posterior duct into the collection
9	1465442	HS	2	CHD and Primary confluence	E4	-	E4	No extravasation
10	1482834	IK	2	Accessory duct draining segment 8	-	A	A	Extravasation from segment 8 duct into segment 8
11	1512467	MS	1	NA	A	-	A	No extravasation
12	1515653	J	1	NA	-	A	A	Extravasation from cystic duct stump into the collection
13	1508360	JS	2	Lateral branch of left hepatic duct	-	C	C	Extravasation from lateral branch of Left hepatic duct into the collection
14	1510473	RK	1	NA	-	-	-	No extravasation
15	1522480	BK	1	NA	A	A	A	Extravasation from cystic duct stump into the collection
16	1523125	VK	2	Suprapancreatic CBD and CHD	E3	-	E3	No extravasation
17	1504215	SK	1	NA	-	A	A	Extravasation from cystic duct stump into the collection
18	1559011	RK	2	Medial branch of Left hepatic duct	-	C	C	Extravasation from medial branch of left hepatic duct into collection
19	1591354	BK	2	CHD and Primary confluence	E4	E4	E4	Extravasation at level of primary confluence into the collection
20	1576253	PD	1	NA	B	-	B	No extravasation
21	1558352	GK	2	Suprapancreatic CBD and CHD	E3	E3	E3	Extravasation from CHD into the collection
22	1618460	AR	2	CHD	E3	E3	E3	Extravasation from CHD into the collection

S.No.	MRD	INITIALS	Intervention	Surgery/ ERCP	Findings	Strasberg classification on basis of Surgical/ERCP findings
1	1352571	NT	Surgery	Hepaticojejunostomy	Prominent Segment 5 Duct with discontinuity of duct just distal to its fusion with right hepatic duct with free flow of bile into the surgical drain	C
2	1362823	S	ERCP	CBD STENTING AND SPHINCTEROTOMY	Extravasation of Contrast seen from cystic duct stump	A
3	1350133	PD	ERCP	CBD STENTING AND SPHINCTEROTOMY	Extravasation of CONTRAST SEEN from cystic duct stump	A
4	1370718	SW	ERCP	CBD STENTING AND SPHINCTEROTOMY	Extravasation of Contrast seen from cystic duct stump	A
5	1445530	SK	ERCP	CBD STENTING AND SPHINCTEROTOMY	Extravasation of CONTRAST SEEN from cystic duct stump	A
6	1461760	ZK	ERCP	CBD STENTING AND SPHINCTEROTOMY	Extravasation of CONTRAST SEEN from Right secondary biliary radicle	C
7	1400796	MK	Surgery	Hepaticojejunostomy	Biliary collection in gb fossa,CHD Stump of 2cm present from primary confluence with free flow of bile	E3
8	1467399	D	Surgery	Hepaticojejunostomy	Transected Right posterior duct with free flow of bile	C
9	1465442	HS	Surgery	Hepaticojejunostomy	Biliary collection in perihepatic location, Injury of CHD, Hila and Proximal Right ductal system present	E4
10	1482834	IK	Surgery	Diagnostic Laparoscopy	No Bile leak after dissection of right anterior and posterior ducts	-
11	1512467	MS	ERCP	CBD STENTING AND SPHINCTEROTOMY	CHD and CBD Normal, Extravasation of contrast from cystic duct stump	A
12	1515653	J	ERCP	CBD STENTING AND SPHINCTEROTOMY	Extravasation of contrast from cystic duct stump, CBD AND CHD NORMAL	A
13	1508360	JS	ERCP	LHD STENTING AND SPHINCTEROTOMY	Extravasation of CONTRAST SEEN FROM LEFT SECONDARY BILIARY RADICLE	C
14	1510473	RK	ERCP	CBD STENTING AND SPHINCTEROTOMY	Extravasation of contrast from cystic duct stump, CBD AND CHD NORMAL	A
15	1522480	BK	ERCP	CBD STENTING AND SPHINCTEROTOMY	Extravasation of contrast seen from cystic duct stump, CBD and CHD Normal	A
16	1523125	VK	Surgery	Hepaticojejunostomy	Biliary collections in Subphrenic and Perihepatic location, Hila visualized with CHD and upper part of CBD not visualized with free flow of bile	E3
17	1504215	SK	ERCP	CBD STENTING AND SPHINCTEROTOMY	Extravasation of contrast seen from cystic duct stump, CBD and CHD Normal	A
18	1559011	RK	ERCP	LHD STENTING AND SPHINCTEROTOMY	Extravasation of contrast seen from Left ductal system,CBD and CHD normal	C
19	1591354	BK	Surgery	Hepaticojejunostomy	Biliary collection in gb fossa, Non visualization of the primary confluence with Stump of 2cm present from RHD	E4
20	1576253	PD	ERCP	CBD STENTING AND SPHINCTEROTOMY	CBD and CHD normal	-
21	1558352	GK	Surgery	Hepaticojejunostomy	Primary confluence visualized, CHD and Suprapancreatic CBD not visualized with free flow of bile	E3
22	1618460	AR	Surgery	Hepaticojejunostomy	Stump present just below the hila	E3

S.No.	MRD	INITIALS	AGE	SEX	CHIEF COMPLAINTS	MECHANISM OF INJURY	If Iatrogenic, Specify	HAEMOGLOBIN	TLC	PLATELETS	T. BILIRUBIN	D. BILIRUBIN	SGOT	SGPT	ALP	ALBUMIN
23	1621696	K	54	2	Pain abdomen,Fever	1	Lap cholecystectomy	9.2	12.1	288	0.88	0.17	99	77	319	4.1
24	1453159	SK	60	2	Fever, pain abdomen,generalized weakness	1	Lap cholecystectomy	8.6	9.4	496	0.22	0.14	37	20	289	2.5
25	1260249	MB	26	2	Pain abdomen,Fever,Icterus	1	Lap cholecystectomy	8.3	17.5	290	2.1	1.4	25	48	287	4.8
26	1281630	HK	57	2	Pain abdomen,fever	1	Lap cholecystectomy	10.7	14.2	463	0.65	0.24	29	33	255	2.8
27	1268159	TK	36	2	Pain abdomen	1	Lap cholecystectomy	7.3	7.1	417	1.26	0.87	103	62	243	1.7
28	1307316	J	27	1	Pain abdomen	2	-	11.6	13.6	280	0.7	0.37	14	17	138	3.4
29	1632117	T	14	1	Road side accident with pain abdomen	2	-	8.7	17.2	432	1.3	0.99	12	9	196	3.4
30	1009229	R	36	2	Fever, generalized weakness	1	Lap cholecystectomy	9.2	13.3	583	0.34	0.11	36	14	264	2.68
31	1622235	ZA	35	1	pain abdomen, generalized weakness	1	Lap cholecystectomy	11.4	6.1	188	1.2	0.7	18	14	218	3.3
32	1628150	A	30	1	Pain abdomen, Icterus	1	Lap cholecystectomy	9.8	12.8	216	1.8	0.55	36	34	312	3.1
33	1563919	S	65	1	Pain abdomen,generalized weakness,bilious discharge from surgical drain	1	Open cholecystectomy	9.3	14.5	318	1.4	0.78	54	36	276	3.6
34	1635332	V	27	1	Pain abdomen	2	-	12.3	12.6	540	0.96	0.35	31	19	348	3.1
35	1247347	A	68	2	Pain abdomen	1	Open cholecystectomy	10.8	7.9	325	1.1	0.65	28	20	260	3.8
36	1713668	R	3	1	Road side accident with pain abdomen	2	-	8.2	15.6	176	0.8	0.56	102	78	367	2.6
37	1367453	RK	52	1	Fever	1	Lap cholecystectomy	11.6	13.1	187	0.9	0.7	46	44	135	3.3
38	1436542	V	29	1	Pain abdomen	1	Lap cholecystectomy	10.8	11.1	256	0.8	0.5	38	40	210	3.6
39	1198765	RD	61	2	Fever,generalized weakness	1	Lap cholecystectomy	9.2	14.2	330	0.7	0.4	53	28	100	2.8
40	1564376	P	40	2	Pain abdomen	1	Lap cholecystectomy	10	13.2	530	1.2	0.9	26	34	180	3.8
41	1654765	AK	55	2	Generalized weakness, Fever	1	Open cholecystectomy	10.1	9.2	480	0.6	0.4	34	28	160	3.5
42	1465398	RK	36	2	Pain abdomen	1	Lap cholecystectomy	9.3	7.4	290	1	0.8	28	26	155	3.1

S.No.	MRD	INITIALS	CREATININE	UREA	ANY OTHER POSITIVE INVESTIGATION	VARIANT ANATOMY	IF PRESENT, SUBTYPE	BILIARY STRICTURES (on Non contrast MRCP)	IF PRESENT, SITE	CYTIC DUCT LEAK (on non-contrast MRCP)	BILE DUCT LEAK(on non contrast MRCP)	TRANSECTION OF HEPATIC DUCT(Non contrast MRCP)
23	1621696	K	0.84	15	NA	2	Right Posterior Duct Draining into CHD	1	NA	1	2	2
24	1453159	SK	0.99	21	NA	2	Segment 5 duct draining into Right posterior duct, Segment 8 duct draining into CHD	2	Right posterior duct	1	1	1
25	1260249	MB	0.24	9	NA	1	NA	2	Common Hepatic duct	1	1	1
26	1281630	HK	0.58	20	NA	2	Right Posterior Duct Draining into Left hepatic duct	1	NA	1	2	2
27	1268159	TK	0.33	5	NA	2	Trifurcation	1	NA	1	2	2
28	1307316	J	0.43	13	NA	1	NA	1	NA	1	2	2
29	1632117	T	0.88	28	NA	1	NA	1	NA	1	1	1
30	1009229	R	0.58	16	NA	1	NA	1	NA	1	1	1
31	1622235	ZA	0.8	16	NA	2	Right Posterior Duct Draining into CHD	1	NA	1	1	1
32	1628150	A	0.78	23	NA	1	NA	1	NA	1	2	2
33	1563919	S	0.65	32	NA	2	low anteromedial insertion of cystic duct	1	NA	1	1	1
34	1635332	V	0.39	27	INR= 1.7	1	NA	1	NA	1	2	2
35	1247347	A	0.76	25	NA	1	NA	1	NA	1	2	2
36	1713668	R	0.41	8	NA	1	NA	1	NA	1	1	1
37	1367453	RK	0.66	18	NA	1	NA	1	NA	1	1	1
38	1436542	V	0.54	24	NA	1	NA	1	NA	1	1	1
39	1198765	RD	0.52	10	NA	2	low anteromedial insertion of cystic duct	1	NA	1	1	1
40	1564376	P	0.54	14	NA	1	NA	1	NA	1	1	1
41	1654765	AK	0.65	22	NA	1	NA	2	Right anterior duct	1	1	1
42	1465398	RK	0.43	16	NA	1	NA	2	Right posterior duct	1	1	1

S.No.	MRD	INITIALS	If Transection present, Hepatic duct involved	DILATED IHBR	DILATED CBD	FREE FLUID	BILIOMA FORMATION	IF Present, SITE	LENGTH OF CBD INTACT(cm)	CONTRAST USED	If yes, Extravastion present	Extravasation from Cystic duct	Extravasation from Bile duct
23	1621696	K	Right hepatic duct	2	1	1	2	PERIHEPATIC LOCATION	4.8	2	2	1	2
24	1453159	SK	NA	2	1	1	1	NA	5.3	2	1	1	1
25	1260249	MB	na	2	1	1	1	NA	4	2	1	1	1
26	1281630	HK	Right anterior duct	2	1	1	2	GB FOSSA AND SUBHEPATIC LOCATION	5.8	2	2	1	2
27	1268159	TK	Right anterior duct	1	1	1	2	GB FOSSA	5.5	2	2	1	2
28	1307316	J	Right posterior duct	2	1	2	2	PERIHEPATIC LOCATION	5.6	2	2	1	2
29	1632117	T	NA	1	1	2	2	SUBHEPATIC AND RIGHT PERIHEPATIC LOCATION	4.8	2	2	1	2
30	1009229	R	NA	1	1	2	2	PERIHEPATIC LOCATION	5.4	2	1	1	1
31	1622235	ZA	NA	1	1	2	2	GB FOSSA	4	2	1	1	2
32	1628150	A	CHD	1	1	1	2	GB FOSSA AND PERIHEPATIC LOCATION	3.2	2	2	1	2
33	1563919	S	NA	1	1	1	2	GB FOSSA AND SUBHEPATIC LOCATION	5.9	2	2	1	2
34	1635332	V	CBD	1	1	1	2	PERIHEPATIC LOCATION	4.1	2	2	1	2
35	1247347	A	Right hepatic duct	1	1	2	2	GB FOSSA AND PERIHEPATIC LOCATION	5.5	2	2	1	2
36	1713668	R	NA	1	1	1	2	Subhepatic and left perihepatic location	3.1	2	2	1	2
37	1367453	RK	NA	1	2	1	1	NA	5.2	2	1	1	1
38	1436542	V	NA	1	1	2	1	NA	4.8	2	1	1	1
39	1198765	RD	NA	1	1	1	1	NA	5.6	2	1	1	1
40	1564376	P	NA	1	1	2	1	NA	4.9	2	1	1	1
41	1654765	AK	NA	2	1	1	1	NA	5.7	2	1	1	1
42	1465398	RK	NA	2	1	1	1	NA	6	2	1	1	1

S.No.	MRD	INITIALS	TRANSECTION OF HEPATIC DUCT (non contrast and contrast MRCP)	Transection seen on non contrast and Contrast , Specify	Strasberg Classification on non-contrast MRCP	Strasberg Classification on Contrast MRCP	Strasberg classification on combined non contrast and contrast MRCP	comments
23	1621696	K	2	Right hepatic duct	C	C	C	Extravasation from Right hepatic duct into collection
24	1453159	SK	1	NA	B	B	B	No extravasation, Narrowed Right posterior duct with its non opacification with opacified Seg 6,7 and 5
25	1260249	MB	1	NA	E2	E2	E2	Non opacification of CHD just distal to primary confluence
26	1281630	HK	2	Right anterior duct	C	C	C	Extravasation from Right anterior duct into collection
27	1268159	TK	2	Right anterior duct	C	C	C	Extravasation from Right anterior duct into collection
28	1307316	J	2	Right posterior duct	C	C	C	Extravasation from Right posterior duct into the collection
29	1632117	T	2	Right posterior duct	-	C	C	Extravasation from Right posterior duct into the collection
30	1009229	R	1	NA	-	-	-	No extravasation
31	1622235	ZA	2	CHD	-	E2	E2	Extravasation from proximal CHD into the collection
32	1628150	A	2	CHD	E3	E3	E3	Extravasation from CHD into the collection
33	1563919	S	2	Segment 5 Duct	-	C	C	Extravasation from Segment 5 duct into the drain in subhepatic space
34	1635332	V	2	CBD	E1	E1	E1	Extravasation from CBD approx 4-4.5 cm from hepatic hilum
35	1247347	A	2	Right hepatic duct	C	C	C	Extravasation from right hepatic duct into collection
36	1713668	R	2	Left Hepatic duct	-	C	C	Extravasation from Left hepatic duct into collection
37	1367453	RK	1	NA	-	-	-	No extravasation
38	1436542	V	1	NA	-	-	-	No extvavasation
39	1198765	RD	1	NA	-	-	-	No extravasation
40	1564376	P	1	NA	-	-	-	No extprvasation
41	1654765	AK	1	NA	B	-	-	No extasvasation
42	1465398	RK	1	NA	B	-	-	No extravasation

S.No.	MRD	INITIALS	Intervention	Surgery/ ERCP	Findings	Strasberg classification on basis of Surgical/ERCP findings
23	1621696	K	Surgery	Hepaticojejunostomy	Transected Right hepatic duct with free flow of bile	C
24	1453159	SK	Surgery	Hepaticojejunostomy	Stricture of Right posterior duct, no collection	B
25	1260249	MB	Surgery	Hepaticojejunostomy	CHD injury, No active bile leak, collection seen in GB fossa	E2
26	1281630	HK	Surgery	Hepaticojejunostomy	Active leak of bile from Right anterior ductal system with injury of right anterior duct	C
27	1268159	TK	Surgery	Hepaticojejunostomy	Active leak of bile from Right anterior ductal system with injury of right anterior duct	C
28	1307316	J	Surgery	Hepaticojejunostomy	Transected Right posterior duct with free flow of bile	C
29	1632117	T	Surgery	Hepaticojejunostomy	Right posterior duct injury with free flow of bile	C
30	1009229	R	ERCP	CBD STENTING AND SPHINCTEROTOMY	Extravasation of contrast from cystic duct stump	A
31	1622235	ZA	ERCP	CBD STENTING AND SPHINCTEROTOMY	Extravasation of contrast from CHD	E2
32	1628150	A	ERCP	CBD STENTING AND SPHINCTEROTOMY	Extravasation of contrast from CHD, primary confluence intact	E3
33	1563919	S	ERCP	CBD STENTING AND SPHINCTEROTOMY	CBD and CHD Normal	-
34	1635332	V	Surgery	Hepaticojejunostomy	CBD Injury with CBD stump approx 4cm from hilum with free flow of bile	E1
35	1247347	A	Surgery	Hepaticojejunostomy	Free flow of Bile from right hepatic duct with transection of duct	C
36	1713668	R	ERCP	LHD STENTING AND SPHINCTEROTOMY	Extravasation of contrast from Left hepatic duct	C
37	1367453	RK	ERCP	Diagnostic ERCP	No leak	-
38	1436542	V	Surgery	Diagnostic Laparoscopy	No leak	-
39	1198765	RD	ERCP	Diagnostic ERCP	No leak	-
40	1564376	P	Surgery	Diagnostic Laparoscopy	No leak	-
41	1654765	AK	Surgery	Diagnostic Laparoscopy	No stricture identified	-
42	1465398	RK	Surgery	Diagnostic Laparoscopy	No stricture identified	-

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Subject:: Approval of Plan of Thesis.

This is to inform you that the Faculty of Medical Sciences in its meeting held on 25.09.2023 has approved the plan of thesis of **Kanav Gupta**, a student of your college for **MD Radio-diagnosis** along with the names of Supervisor/Co-Supervisor as under:-

Topic Plan of Thesis
Role of mrcp in evaluation of bile duct injuries .

Supervisor
Dr. Chandan Kakkar
Assoc. Prof.,
Dept. of Radio-diagnosis

Co-Supervisor:-
Dr. Satpal Singh Virk
Prof. & Head
Dept. of G.E. Surgery

The student may submit the thesis in triplicate alongwith the plan in triplicate also, to the Controller of Examinations, BFUHS, Faridkot, at least six months before the commencement of theory examination, if he/she is otherwise eligible to take the examination. He /She may be directed to attach a photocopy of this letter with the forwarding letter while submitting thesis in the University along with the letter of approval of University for change of supervisor/Co-Supervisor, change of topic, if any.

Controller of Examinations

Note :

1. *If any discrepancy found regarding topic of thesis or Supervisor/Co-Supervisor, inform undersigned within one month after issue of this letter.*

ROLE OF MRCP IN EVALUATION OF BILE DUCT INJURIES

THESIS PROPOSAL

FOR APPROVAL OF SUBJECT OF THESIS TO BE SUBMITTED IN

PARTIAL FULFILMENT OF THE REQUIREMENTS

FOR THE DEGREE OF

MD

In

RADIODIAGNOSIS

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ABSTRACT OF PLAN OF THESIS

Title	ROLE OF MRCP IN EVALUATION OF BILE DUCT INJURIES
For the degree of	MD(Radiodiagnosis)
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INTRODUCTION

Bile duct Injuries can manifest in form of biliary dilatation, excision injury, stricture, fluid collection, and free fluid collection. Because clinical signs and symptoms of bile leaks are non-specific and delay in recognition of bile leaks is associated with high morbidity and mortality, imaging is crucial for establishing an early diagnosis and guiding its treatment.

Magnetic Resonance cholangiopancreatography (MRCP) is a non-invasive imaging technique to visualize the intra and extrahepatic biliary tree and pancreatic ductal system. Hence, MRCP can be a useful diagnostic tool to characterize and anatomically classify these bile duct injuries for planning reparative surgery and other treatment options.

AIM OF STUDY

1. To assess the role of MRCP in evaluation of Bile duct injuries.
2. To assess the added advantage of using intravenous hepatobiliary contrast in evaluation of Bile duct injuries wherever possible.
3. To correlate the imaging findings with ERCP, surgical findings or clinical follow up wherever possible.

Materials and Methods

This study will be conducted over a period of one and half year from 15th September 2022 to 15th March 2024 on patients with clinical evidence of bile duct injury referred for MRCP to the Department of Radio-diagnosis, Dayanand Medical College & Hospital, Ludhiana.

Clinical Significance

To determine the utility of MRCP in evaluating bile duct injuries and assessing its role as a road map for management of bile duct injuries.

Keywords: Bile duct injuries, MRCP

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Candidate	Co-supervisor	Supervisor	Principal

CERTIFICATE OF FACILITIES AVAILABLE

This is to certify that the facilities for work on the subject of thesis titled **"ROLE OF MRCP IN EVALUATION OF BILE DUCT INJURIES"** exist in the Department of Radiodiagnosis, DMC&H, Ludhiana and will be provided to the candidate. We will see that the data being included in the thesis is genuine and is collected by the candidate himself under our supervision and guidance.

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PROFORMA FOR REGISTRATION OF SUBJECT FOR DISSERTATION

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4	DATE OF ADMISSION OF COURSE	07-03-2022
5	TITLE OF THE TOPIC	ROLE OF MRCP IN EVALUATION OF BILE DUCT INJURIES

6. BRIEF RESUME OF THE INTENDED WORK

6.1 NEED FOR THE STUDY

Traumatic and iatrogenic bile leaks have become more prevalent in recent years due to an increased propensity toward nonsurgical management of patients with liver trauma and an overall increase in the number of hepatobiliary surgeries being performed. Because clinical signs and symptoms of bile leaks are nonspecific and delay in the recognition of bile leaks is associated with high morbidity and mortality rates, imaging is crucial for establishing an early diagnosis and guiding the treatment.[1]

Traumatic Biliary tract injuries are associated with multiple organ injuries—most commonly, hepatic, splenic, and duodenal injuries, which have a reported prevalence of 91%, 54%, and 54%, respectively.[2,3] The gallbladder is the most common location of biliary injury in blunt trauma, followed by the extra- and intrahepatic bile ducts, respectively. Injuries to the extrahepatic bile ducts typically occur at sites of anatomic fixation, such as the intrapancreatic portion of the common bile duct (CBD), usually from acute deceleration. An alternate mechanism of injury to the CBD involves traumatic elevation of the liver with stretching of and trauma to the CBD.[2] Injuries to the intrahepatic bile ducts are seen in patients with parenchymal liver injury.

The rate of bile duct injuries is slightly higher using laparoscopic surgery than open surgery (0.5% and 0.15%, respectively). In general, a laparoscopic approach allows less complete traction of the gallbladder and cystic duct than open surgery. This can lead to incomplete isolation of anatomical structures and/or traction injury.[4]

Bile duct injuries manifests as leak, stricture, complete transection and excision of a segment of duct and ligation of a major bile duct.[5] Bile duct injuries can be caused by erroneous cutting of bile ducts, accidentally misplaced clips, laceration, occlusion or peri ductal leakage due to thermal injury by electrocautery leading to fibrosis.[4,6] Common sites of biliary leaks include injured ducts, the cystic duct stump and the gallbladder stump. Fluid collections in the gallbladder

bed occur in up to 14% of patients following cholecystectomy and tend to resolve spontaneously; collections persisting for more than a week or fluid outside the gallbladder bed raise the suspicion of a biliary leak and/or injury.[7] The initial treatment of these patients depends on the type of injury and the time of its recognition.

Therefore, it is essential to determine the morphological details of the injury and define the anatomy of proximal biliary tree; this would determine strategy for biliary reconstruction and significantly affect the long-term prognosis.[5,6,8]

Various modalities used in the diagnosis of bile duct injuries are Ultrasound (USG), Percutaneous Transhepatic Cholangiography (PTC), Endoscopic Retrograde Cholangiopancreatography (ERCP), direct cholangiography, and Magnetic Resonance Cholangiopancreatography (MRCP).

These techniques allow definition of the level of injury, identification of fluid collections or the presence of ascites, and detection of the possibility of vascular damage and lobar atrophy. Furthermore, the main role of these investigations, coupled with percutaneous aspiration, is to establish the presence of bile in the peritoneal cavity and eventually to drain it.

Hepatobiliary scintigraphy is good for the detection of bile leakage; however, this technique lacks the anatomic detail needed for preoperative planning.

The main purpose of investigation should be to establish the diagnosis with the least risk of morbidity and the lowest cost. In particular, the main roles of the more invasive procedures, such as ERCP and PTC, are to provide exact anatomic diagnosis and to treat the injury by decompressing the biliary tree or dilating it.[9] In general, PTC is superior to ERCP in the case of biliary excision in providing critical anatomic details of the proximal biliary tree. Evaluation by ERCP in the case of complete stenosis is limited by the fact that it shows only the lower end of the obstruction and fails to delineate the proximal biliary tract.[10] Nevertheless, these procedures are invasive and have the potential for serious complications such as acute pancreatitis,

hemorrhage, infection, perforation, aspiration, and adverse reaction to contrast media or premedication.[11]

MR cholangiography (MRCP) is a non invasive and accurate technique for assessing bile duct injuries after surgery.[9] This technique allows exact definition of the level of biliary injury, which is essential for preoperative planning. Compared with ERCP, MRCP presents the great advantages of documenting the biliary tree obstruction upstream to a lockout, locating the presence of abscesses or perihepatic fluid collections and showing the site of bile leakage; it also allows parallel evaluation of the liver parenchyma and pancreas.[12]

In MRCP, the basic principle is that body fluids like bile and pancreatic secretions, have high signal intensity on heavily T2-weighted magnetic resonance sequences which appear bright, while the background tissues generate little signal and appear dark. MRCP is usually performed with heavily T2W sequences by using fat spin echo or SSFE(Single Shot Fast Spin Echo) technique and both a thick collimation (Single section) and thin collimation (multisection) technique with a torso phased array coil. The coronal plane is used to provide a cholangiography display and the axial plane is used to evaluate the pancreatic duct and CBD.[13]

6.2 REVIEW OF LITERATURE

Tahir R. Khalid, V. Javier Casillas et al (2000) did a prospective study in which MRCP was performed in 10 postoperative patients (nine female and one male, ranging in age from 17 to 79 years) suspected of having bile duct injury as a result of surgery. Presence or absence of biliary dilatation, excision injury, stricture, fluid collection, and free fluid was noted. Excision injury was diagnosed if a segment of bile duct was not visible on any of the MRCP sequences. Positive cases were classified according to anatomic location and extent of injury. Results were compared with endoscopic retrograde cholangiopancreatography in five patients, percutaneous transhepatic cholangiography in one, surgery in four, and clinical follow-up in three. S. Three patients had normal findings on MRCP and remained asymptomatic on clinical follow-up. Four patients had bile duct excision injury on MRCP that was surgically proven, and one had stricture, confirmed by percutaneous transhepatic cholangiography. Of these five patients, one had Bismuth type I injury, two had type II, one had type III, and one had type IV. Two patients had findings suggestive of cystic duct leak on MRCP that were confirmed on cholangiography. They concluded that MRCP can accurately diagnose postoperative biliary strictures and excision injuries and can characterize and anatomically classify these injuries for planning reparative surgery.[5]

Luis Bujanda, Mari M. Calvo et al (2003) performed a prospective blind study ,contrasting MRCP and ERCP in 10 patients with suspected postoperative biliary tract lesions. MRCP was performed less than 72 h before ERCP. Final diagnosis was made on the basis of findings at surgery and ERCP. The presence of biliary dilatation, excision injury, stricture, fluid collection and free fluid was analyzed. The mean patient age was 66.5 years. There were three males and seven females. The type of postoperative lesion (Bergman classification) were- five patients type C, three type D, one type B and one type A. Diagnostic failure was recorded in two cases with ERCP, while in five patients it was unable to define a therapeutic approach. In contrast, MRCP correctly diagnosed all patients. They concluded that MRCP is effective in diagnosing

postoperative biliary tract lesions, and can help decide the best therapeutic approach.[14]

Alfonso Ragozzino, Rosaria De Ritis et al (2004) did a prospective study on Nineteen patients (14 women and five men; mean age, 47 years; age range, 24–75 years) with suspected bile duct injury as a result of laparoscopic cholecystectomy (17 patients) and open cholecystectomy (two patients).MR images were evaluated for bile duct discontinuity, presence or absence of biliary dilation, stricture, excision injury, free fluid, and collections. Bile duct excision and stricture were classified according to the Bismuth classification. Final diagnosis was made on the basis of findings at surgery in 15 patients, on percutaneous transhepatic cholangiography (PTC) in one patient, and on endoscopic retrograde cholangiography (ERC) and at clinical follow-up until hospital discharge in the remaining three patients. In 16 patients, injury of the bile duct was observed. Two patients had Bismuth type I injury; one patient, type II injury; 11 patients, type III injury; and one patient each, type IV and V injuries. Three patients showed findings suggestive of leakage from the cystic duct remnant, which were confirmed on ERC. They concluded that MR cholangiography is an accurate diagnostic technique in the identification of postoperative bile duct injuries. This technique allows exploration above and below the level of obstruction, a resource provided by neither ERC nor PTC, and allows the accurate classification of these injuries, which is essential for treatment planning.[9]

Mi-Suk Park, Ki Whang Kim et al (2004) did a conventional heavily T2-weighted MR cholangiography with MnDPDP-enhanced T1-weighted MR cholangiography and ERCP in seven patients with high clinical suspicion of biliary complications after laparoscopic cholecystectomy. The final diagnoses of complications were classified according to the presence and degree of bile duct injury, bile leakage, and retained stones. The diagnoses on MR cholangiography were as follows: complete transection and occlusion of the common bile duct with bile leakage, partial strictures of the common bile duct with bile leakage,

cystic duct leakage, partial ligation of an aberrant right hepatic duct, and hemorrhage without biliary complication. The final diagnoses at surgery and ERCP were as follows: complete transection and occlusion of the common bile duct with bile leakage, partial strictures of the common bile duct with bile leakage, cystic duct leakage, partial ligation of an aberrant right hepatic duct, and hemorrhage without biliary complication. MR cholangiography accurately yielded the same findings as the final diagnoses, except in one case with partial stricture of the bile duct with bile leakage (overdiagnosed as complete occlusion on MR cholangiography). They concluded that Combined conventional T2-weighted and MnDPDP-enhanced T1-weighted MR cholangiography may eliminate the use of other studies for the imaging of biliary complications after cholecystectomy if this preliminary data can be verified in a larger study.[15]

M. Aduna, J. A. Larena et al (2005) did a prospective study on 34 patients with clinical suspicion of bile duct leak after laparoscopic cholecystectomy. They assessed the role of mangafodipir enhanced magnetic resonance (MR) cholangiography in the detection and location of bile duct leaks. In 20 of 34 patients, bile duct leakage was proved by surgery, endoscopic retrograde cholangiography, or drainage. Contrast enhancement displayed the leakage in 19 of 20 patients and ruled out leaks in the other 14 patients (95% sensitivity, 100% specificity). The leak site was depicted in 14 patients and contrast-enhanced MR cholangiography successfully located the origin of the leak in 11 patients. They concluded that Contrast-enhanced MR cholangiography with intravenous mangafodipir trisodium can accurately diagnose the presence and location of bile duct leaks in patients who have undergone laparoscopic cholecystectomy.[16]

L. Salvolini,C. Urbinati et al (2011) assessed the usefulness of contrast-enhanced magnetic resonance cholangiography (CE-MRC) with liver-specific contrast agent in evaluating the biliary tree after hepatic surgery. A total of 142 patients with suspected biliary complications after liver surgery underwent hepatobiliary MR before and after administration of gadolinium ethoxybenzylicdiethylene-

triaminepentaacetic acid (Gd-EOB-DTPA). Unenhanced MR cholangiopancreatography (MRCP) and postcontrast MRC were obtained in all patients. Blinded image evaluation and semiquantitative analysis comparing. MRCP and CE-MRC were performed by two experienced radiologists. In all cases, optimal postcontrast visualization of the biliary tract was obtained. In 22 patients, a postsurgical biliary complication was confirmed. MRCP detected 64% of lesions, but in 36% of cases, an alteration was only suspected but not clearly defined. CE-MRC allowed definite diagnosis in 100% of cases. They concluded that Hepatobiliary-specific contrast agents allow for accurate and extensive study of biliary tract alterations, especially in assessing postsurgical complications.[17]

M. Kantarci, B.Pirimoglu et al (2013) did a prospective study on ninety-nine patients with suspected biliary complications who underwent routine T2w-MRC and T1w contrast-enhanced (CE) MRC using Gd-EOB-DTPA to identify biliary leaks. Two observers reviewed the image sets separately and together. MRC findings were compared with those of surgery and percutaneous transhepatic cholangiopancreatography. The sensitivity, specificity and accuracy of the techniques in identifying biliary leaks were calculated. Accuracy of locating biliary leaks was superior with the combination of Gd-EOB-DTPA-enhanced MRC and T2w-MRC ($P < 0.05$).The mean sensitivities were 79 % vs 59 %, and the mean accuracy rates were 84 % vs 58 % for combined CE-MRC and T2w-MRC vs sole T2w-MRC. Nineteen out of 21 patients with biliary-cyst communication, 90.4 %, and 12/15 patients with post-traumatic biliary extravasations, 80 %, were detected by the combination of Gd-EOB-DTPA-enhanced MRC and T2w-MRC images, $P < 0.05$.Gd-EOB- They concluded that DTPA-enhanced MRC yields information that complements T2w-MRC findings and improves the identification and localisation of the bile extravasations (84 % accuracy, 100 % specificity, $P < 0.05$). [18]

6.3 AIMS AND OBJECTIVES OF THE STUDY

1. To assess the role of MRCP in evaluation of Bile duct injuries.
2. To assess the added advantage of using intravenous hepatobiliary contrast in evaluation of Bile duct injuries wherever possible.
3. To correlate the imaging findings with ERCP, surgical findings or clinical follow up wherever possible.

7.0 MATERIALS AND METHODS:

7.1 SOURCE OF DATA

This study will be conducted over a period of one and half year from 15th September 2022 to 15th March 2024 on patients with clinical evidence of bile duct injury referred for MRCP to the Department of Radio-diagnosis, Dayanand Medical College & Hospital, Ludhiana.

7.2 METHOD OF COLLECTION OF DATA

This study will be conducted over a period of one and half year from 15th September 2022 to 15th March 2024 on patients with clinical evidence of bile duct injury referred for MRCP to the Department of Radio-diagnosis, Dayanand Medical College & Hospital, Ludhiana. Informed Consent will be obtained from all patients/guardians and relevant detailed history will be elicited. Findings of general physical and systemic examination will be recorded. Before starting the study, the procedure will be explained to the patient in his/her vernacular language to allay the fear and anxiety. MRCP will be performed on Siemens 3T MRI machine and Intravenous contrast will be given if needed.

Inclusion Criteria

All patients with clinical evidence of bile duct injury undergoing Magnetic resonance Cholangiopancreatography.

Exclusion Criterion

1. Anyone who is unwilling to participate in the study.
2. Patients who are already operated upon for bile duct injuries.

MR imaging technique

All patients will undergo a multiplanar, multi-sequential MR imaging of upper abdomen on a MAGNETOM SKYRA 48 Channel 3 Tesla MRI Scanner by Siemens, Germany.

Following MR imaging sequences to be included:

1. T2 haste axial
2. T2 haste fat sat axial
3. T2 haste coronal
4. T2 trufi axial
5. T1 VIBE in-out phase axial

6. Diffusion Weighted Imaging(DWI) in axial plane acquired at 3 b-values of 50, 400, 800.

7. T2 TSE 3D coronal.

8. Contrast Enhanced MRI

Contrast Enhanced MRI will be performed using three-dimensional volume interpolated breath hold examination (3D VIBE) sequence in the transverse plane.

A rapid bolus of 0.1mmol/kg body weight gadobenate dimeglumine will be given through a peripheral vein followed by 10 ml of saline. Images will be acquired in arterial, portal and venous phase. Delayed phase images (1 hour after contrast administration) will be acquired if indicated.

	TR	TE	FOV (R)	FOV (P)	SLICE	SLICE THICK	GAP	FLIP ANGLE	FAT SAT	MATRIX	FLOW COMP	PHASE ENC	ORIENTATION
T1 vibe Fat Sat	3.31 ms	1.3 ms	380 mm	81.3%	72	3 mm	1.1 mm	9^0	SPAIR	182*320	NO	AP	Transverse
T1 vibe In-out phase	4.34 ms	1.34, 2.76 ms	380 mm	81.3%	72	3 mm	1.1 mm	9^0	NONE	182*320	NO	AP	Transverse
T2 haste fat sat	2000 ms	91 ms	350 mm	78.1%	30	5 mm	2.5 mm	160^0	SPAIR	200*320	NO	AP	Transverse
T2 haste traction	2000 ms	91 ms	360 mm	78.1%	30	5 mm	2.5 mm	160^0	NONE	200*320	NO	AP	Transverse
T2 haste coronal	2000 ms	91 ms	350 mm	100%	35	5 mm	0.5 mm	160^0	NONE	288*320	NO	R-L	Coronal
T2 haste thick slab	4500 ms	734 ms	260 mm	100%	1	50 mm	2.5 mm	180^0	FATSAT	314*448	NO	R-L	
Diffusion	5700 ms	48 ms	380 mm	80.6%	30	5 mm	2.5 mm		SPAIR	108*134		AP	Transverse
T2 TSE 3D CORONAL	1600 ms	623 ms	335 mm	100 %	64	1.5 mm	0 mm	180^0	NONE	320*320	NO	R-L	Coronal
T2 haste coronal thin slab	2000 ms	101 ms	350 mm	100%	30	3 mm	0.2 mm	160^0	SPAIR	205*256	NO	R-L	Coronal
T2 Trufi Axial	382 ms	1.68 ms	380 mm	80.5%	30	5 mm	2.5	50^0	None	206*256		AP	Transverse

OUTCOME: Utility of MRCP in assessing bile duct injuries and its role in clinical management.

STATISTICAL ANALYSIS

Data will be described in terms of range; mean ±standard deviation (± SD), median, frequencies (number of cases) and relative frequencies (percentages) as appropriate. All statistical calculations will be done using (Statistical Package for the Social Science) SPSS 21version (SPSS Inc., Chicago, IL, USA) statistical program for Microsoft Windows.

7.3 DOES THE STUDY REQUIRE ANY INVESTIGATIONS OR INTERVENTIONS TO BE CONDUCTED ON PATIENTS OR OTHER HUMANS OR ANIMALS? IF SO, PLEASE DESCRIBE BRIEFLY.

- The study will be performed on Siemens 3T MRI machine.
- However, the study does not require any intervention to be conducted on patients, other humans or animals.

7.4 HAS ETHICAL CLEARANCE BEEN OBTAINED FROM YOUR INSTITUTION IN CASE OF 7.3?

Yes, Attached herewith.

8. LIST OF REFERENCES

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EOB-DTPA-enhanced MR cholangiography: comparison with T2-weighted MR cholangiography. European Radiology. 2013;23:2713-22.

PROFORMA

S.No. MRD No.

Name Age/Sex

Address

Contact No.

Clinical Evidence

Chief Complaints:

Past History:

General physical examination

Mechanism of injury:

Iatrogenic

Non-iatrogenic

Lab Investigation

- Hemogram
  - Hb
  - TLC
  - Platelets
- LFTs
  - T.bilirubin
  - D.Bilirubin
  - SGOT
  - SGPT
  - ALP
  - Albumin

Signature of Candidate **Signature of Supervisor**

- RFTs

  Creatinine

  Urea

- Any other positive investigation

MRCP FINDINGS

Contrast used:

YES Dose:

Name:

Brand:

NO

Variant anatomy-

Absent

Present

Subtype:

1.Biliary strictures:

Absent

Present

Site:

2. Cystic duct leak:

Absent

Present

3. Bile duct leak:

Absent

Present

4 Occlusion of Hepatic duct:

Absent

Present

5 Transection of Hepatic duct:

Absent

Present

6 Dilated IHBR:

Absent

Present

7 Dilated CBD:

Absent

Present

8.Free fluid:

Absent

Present

9 Bilioma formation

Absent

Present

10 Length of CBD intact:

Classification of injury:

Strasberg Classification

Surgical/ERCP Findings:

Concordance with Surgical/ERCP Findings: YES / NO / NOT AVAILABLE

Signature of Candidate **Signature of Supervisor**

INFORMED PATIENT CONSENT

Date: _____

I…….D/o, W/o, S/o……..…… am willing to participate in the study **"ROLE OF MRCP IN EVALUATION OF BILE DUCT INJURIES"** The procedure with its complications has been explained to me in local vernacular language. I have fully understood that no special tests and extra expenditure in any form, merely for the purpose of thesis is being carried out. I am free to opt out the study any time without assigning any reason.

……. ……
Signature of the Witness Signature of the patient

Name:

Signature of Candidate **Signature of Supervisor**

मरीज अनुमति फार्म

तिथि _____

मैं _____ पत्नी/पुत्र/पुत्री _____

निवासी _____

इस शोधकार्य "**ROLE OF MRCP IN EVALUATION OF BILE DUCT INJURIES**" में भाग लेने के लिए सहमत हूँ। मैं इस शोधकार्य में भाग लेने के लिए अपनी स्वेच्छा से तैयार हूँ। मैं पुष्टि करता/करती हूँ की यह स्वीकृति देने के लिए मुझे कोई आर्थिक प्रलोभन नहीं दिया गया और न ही दबाव डाला गया है। मुझे इस शोधकार्य का उद्देश्य स्पष्ट कर दिया गया है और मुझे यह विश्वास है की यह विज्ञान और मानवता के लाभ के लिए है। मुझे इस शोधकार्य में होने वाले जोखिम के बारे में समझा दिया गया है और मेरी समझ में यह जोखिम बहुत मामुली है।

मैं इस शोधकार्य में भाग लेने के सम्बन्ध में किसी भी समय अपनी अस्वीकृति व्यक्त कर सकता/सकती हूँ और मेरे अस्वीकृति व्यक्त करने का मेरे इलाज पर कोई प्रभाव नहीं पड़ेगा।

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गवाह के हस्ताक्षर	रोगी के हस्ताक्षर/अंगूठे का निशान
नाम:	नाम:

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अन्वेषक के हस्ताक्षर

_____

विद्यार्थी के हस्ताक्षर

ਮਰੀਜ਼ ਰਜ਼ਾਮੰਦੀ ਫਾਰਮ

ਮਿਤੀ_____

ਮੈ_____ਪਤਨੀ/ਪੁੱਤਰ/ਪੁੱਤਰੀ_____

ਵਾਸੀ _____

“ROLE OF MRCP IN EVALUATION OF BILE DUCT INJURIES” ਤੇ ਚਲ ਰਹੀ ਖੋਜ ਵਿਚ ਹਿੱਸਾ ਲੈਣ ਲਈ ਰਜ਼ਾਮੰਦ ਹਾਂ। ਇਸ ਖੋਜ ਕੰਮ ਵਿਚ ਹਿੱਸਾ ਲੈਣ ਲਈ ਮੈ ਆਪਣੀ ਮਰਜ਼ੀ ਨਾਲ ਤਿਆਰ ਹਾਂ। ਮੈ ਇਹ ਦਸਣਾ ਚਾਹੁੰਦਾ ਹਾਂ/ ਚਾਹੁੰਦੀ ਹਾਂ ਕੇ ਇਹ ਰਜ਼ਾਮੰਦੀ ਦੇਣ ਵਾਸਤੇ ਮੈਨੂ ਕਿਸੇ ਵੀ ਤਰਾਂ ਦਾ ਲੋਭ-ਲਾਲਚ ਨਹੀ ਦਿੱਤਾ ਗਿਆ ਅਤੇ ਨਾ ਹੀ ਕੋਈ ਦਬਾ ਪਾਇਆ ਗਿਆ ਹੈ। ਮੈਨੂ ਇਸ ਖੋਜ ਦਾ ਮਨੋਰਥ ਸਮਝਾ ਦਿੱਤਾ ਗਿਆ ਹੈ ਅਤੇ ਮੈਨੂ ਇਹ ਭਰੋਸਾ ਦਵਾਇਆ ਗਿਆ ਹੈ ਕੇ ਇਹ ਖੋਜ ਵਿਗਿਆਨ ਅਤੇ ਮਾਨਵਤਾ ਦੀ ਭਲਾਈ ਲਈ ਹੈ। ਮੈਨੂ ਇਸ ਖੋਜ ਵਿਚ ਹੋਣ ਵਾਲੇ ਖਤਰੇ ਬਾਰੇ ਸਮਝਾ ਦਿੱਤਾ ਗਿਆ ਹੈ ਅਤੇ ਮੈਨੂ ਇਹ ਯਕੀਨ ਹੈ ਕੇ ਇਹ ਖਤਰਾ ਬਹੁਤ ਮਾਮੂਲੀ ਹੈ। ਮੈਨੂ ਇਸ ਖੋਜ ਕੰਮ ਵਿਚ ਹਿੱਸਾ ਲੈਣ ਦਾ ਢੰਗ – ਤਰੀਕਾ ਸਮਝਾ ਦਿੱਤਾ ਗਿਆ ਹੈ।

ਮੈ ਇਸ ਖੋਜ ਕੰਮ ਵਿਚ ਹਿੱਸਾ ਲੈਣ ਬਾਰੇ ਆਪਣੀ ਰਜ਼ਾਮੰਦੀ ਕਿਸੇ ਵੀ ਸਮੇ ਵਾਪਸ ਲੈ ਸਕਦਾ ਹਾਂ/ ਸਕਦੀ ਹਾਂ ਅਤੇ ਮੇਰੀ ਰਜ਼ਾਮੰਦੀ ਵਾਪਸ ਲੈਣ ਦਾ ਮੇਰੇ ਇਲਾਜ ਤੇ ਕੋਈ ਅਸਰ ਨਹੀ ਹੋਵੇਗਾ।

_____ _____

ਗਵਾਹ ਦੇ ਹਸਤਾਖਰ ਮਰੀਜ਼ ਦੇ ਹਸਤਾਖਰ

ਮਿਤੀ_____ ਮਿਤੀ_____

ਪਤਾ _____ ਪਤਾ _____

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ਨਿਰੀਖਕ ਦੇ ਹਸਤਾਖਰ

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ਸਿਖਿਆਰਥੀ ਦੇ ਹਸਤਾਖਰ